PRINCIPLES OF FOOD PROCESSING AND PRESERVATION

RATIONALE

Knowledge and skills related to food processing and preservation are essential for the diploma holder in food technology. In this subject, students are exposed to various techniques of food preservation such as low temperature, high temperature, moisture removal, chemicals, radiation and recent preservation. Relevant skills will also be imparted through this subject.

COURSE OUTCOMES
After going through this course, the students will be able to:
CO1: Apply processes of Sterilization, Pasteurization, Blanching, and Canning.
CO2: Differentiate between sun drying and dehydration & learn methods of dehydration.
CO3: Explain different freezing techniques.
CO4: Summarize the basic concepts of irradiation and microwave heating techniques.
CO5: Use hurdle technology and pulsed electric field techniques for food preservation.

DETAILED CONTENTS

UNIT I
- Aims and objectives of food processing and preservation.
- Classification of foods on the basis of shelf life, pH, origin;
- Different types of food spoilage viz. microbiological, bio-chemical, chemical, physical and their effects on food quality;
- Principles of food preservation.
- Preservation of food by adding preservative (Class-I and Class-II) Definition, types, Class I and Class II preservatives; Introduction, permissible limit and mode of action of sugar, salt, vinegar, benzoic acid, sulphur dioxide and sulphites, nitrates and nitrites, sorbic acid;
- Introduction to pickling process (curing or fermentation with dry salting, fermentation in brine, salting without fermentation);
- Intermediate Moisture Food (IMF) like jam, jelly and marmalade.

UNIT II

Preservation of foods by high temperatures
Introduction, objectives, limitation of blanching and methods of blanching; Introduction, objectives, limitation and methods of sterilization, pasteurization (LTLT, HTST, UHT);
History, general process, advantages of canning of foods, spoilage and defects in cans, type of cans.
UNIT III
Preservation by water removal
Definition, drying as a means of preservation, Differences between sun drying and Dehydration (i.e. Mechanical drying like cabinet, tunnel, kiln, fluidized bed, pneumatic/flash, drum, spray, vacuum and freeze drying of foods), Factors affecting rate of drying, normal drying curve, Types o driers used in the food industry;
Definition evaporation and concentration, names of evaporators used in food industry, concept of freeze concentration and membrane process for food concentrations.
UNIT IV
Food Preservation by Low temperature
Introduction to refrigeration, cool storage and freezing, definition & principle of freezing; factors determining freezing rate; types of freezing i.e. slow freezing, quick freezing; Freezing methods- direct and indirect, still air sharp freezer, blast freezer, fluidized freezer, plate freezer, spiral freezer and cryogenic freezing; introduction to the term freezer burn and recrystallization;
Introduction to thawing, changes during thawing; advantages and limitations of freezing.
UNIT V
Food irradiation, microwave heating and recent advances in food preservation

Introduction, units of radiation, kinds of ionizing radiations used in food irradiation, mechanism of action, uses of radiation processing in food industry, concept of cold sterilization, Radiation doses for spices, onions, potatoes and meat; basic concept of microwave heating.
Introduction to hurdle technology, pulsed electric filed.
Note: Wherever necessary equipment are not available students may be demonstrated that topic in relevant industry or in any other institute.

UNIT I
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About

Early scientific research into food technology concentrated on food preservation. Nicolas Appert's development in 1810 of the canning process was a decisive event. The process wasn't called canning then and Appert did not really know the principle on which his process worked, but canning has had a major impact on food preservation techniques.
Louis Pasteur's research on the spoilage of wine and his description of how to avoid spoilage in 1864 was an early attempt to apply scientific knowledge to food handling. Besides research into wine spoilage, Pasteur researched the production of alcohol, vinegar, wines and beer, and the souring of milk. He developed pasteurization—the process of heating milk and milk products to destroy food spoilage and disease-producing organisms. In his research into food technology, Pasteur became the pioneer into bacteriology and of modern preventive medicine.

- **Food Technology** is a branch of food science that deals with the production processes that make foods. Early scientific research into food technology concentrated on food preservation.
- **Food science** The study of the basic chemical, physical, biochemical, and biophysical properties of foods and their constituents, and of changes that these may undergo during handling, preservation, processing, storage, distribution, and preparation for consumption
- **Food engineering** is a multidisciplinary field of applied physical sciences which combines science, microbiology, and *engineering* education for *food* and related industries.
- **Food preservation** is the process of treating and handling food to stop or slow down food spoilage, loss of quality, edibility, or nutritional value and thus allow for longer food storage. Microorganisms.

The basic purposes of food preservation are:
1. Extension of shelf-life of foods thus increasing the supply.
2. Ensuring the availability of seasonal foods throughout the year.
3. Adding variety to the diet.
4. Saving time by reducing preparation time and energy.

5. Stabilizing firm prices and prices of food.
6. Improving the nutritional qualities.

Aims and objectives of food processing and preservation.

Food preservation prevents losses and wastage of nutrients from foods and allows people to benefit from the nutrient concentrated foods. Enormous reduction in spoilage and wastage of perishable foods builds up the country's economy by making more food available to the people at affordable prices. It provides much needed employment avenues to many individuals in the food processing and allied fields. With the spurt in growth of food preservation industries, the demand for the trained personnel has substantially increased. With the recent liberalization policy and lifting of trade restrictions, there is a vast potential for exports of processed foods. Multinational food giants are finding India as a promising market. In case, Indian products can meet the international standards of quality as well as compete successfully, we can earn valuable foreign exchange.

Availability of cheap labour, Government Subsidy for cold storage and processing units, convenience of roads in case for marketing and transport. Availability of cans, bottles, and other equipment at cheap rate, there is tremendous for export of processed products like Jam, jelly, marmalade, pickles, etc. dehydrated and dried vegetables in addition to domestic demand in India. Five-year tax holiday for new food processing units in fruits and vegetables processing along with other benefits in the budget has bolstered the government's resolution of encouraging growth in this sector.

India is the second-largest producer, next to China, of fruit and vegetables in the world, contributing a total of 150 million tonnes of the produce to the global production annually. But only 2.2% of the fruit and vegetables are processed here as compared to countries like the USA (65%), Philippines (78%) and China (23%). That's why there is a huge opportunity for companies looking at investing in this sector in the country. Although India is a very large producer of fruits, yield levels of most of the fruits are relatively low as compared to those in other major fruit producing countries.
About 25 to 30 per cent of the total production is lost due to spoilage at various post-harvest stages. In value terms, the post harvest wastage and losses per year are estimated at over Rs. 3000 crores. Because of these losses, the per capita availability of fruits is only of the order of 75 gm per person per day, which is just half of the requirements of a balanced diet. This happens due to:

- Lack of Transport
- Lack of Storage facilities
- Poor availability of package materials
- Poor road conditions
- Lack of local cold storage to store the surplus

This results in the inadequate pricing of produce during off season and spoilage. This provides the farmer a higher price on his product, due to palatability of the product.
The major fruits grown are banana, mango, citrus, guava, grapes, apple and pineapple which constituted nearly 80 percent of the total fruit production in the country. Banana has the largest share of 31.7 per cent in total fruit production, followed by mango with 28 per cent. Production of mango has remained almost stagnant during the decade 1983-93. The annual growth in production during 1983-93 was 9.6 per cent in the case of bananas, 10.3 percent for papaya, 9.4 per cent for grapes and 4.7 per cent in respect of citrus fruits. The major fruit producing states are Andhra Pradesh, Maharashtra, Karnataka, Bihar, Uttar Pradesh, Tamil Nadu, Kerala and Gujarat. These eight states contribute 78 per cent of the total fruit production.

The Indian gourmet food market is currently valued at US$ 1.3 billion and is growing at 20 per cent. It is expected to cross US$ 2.8 billion by 2015 and is expected to reach US$ 78 billion by 2018. Share of online food ordering would be in single digits of the overall food ordering business which in 2014 was estimated to be around Rs 5,000-6,000 crore (US$ 800.19-960.12 million). We are growing at 20-30 per cent month-on-month.

Importance and need of Food Processing and Preservation

Food preservation activities are as old as the human race. It had an important role in the spread of civilization. Delay in the consumption or processing of fresh foods alters its freshness, colour, texture, palatability and nutritive value, organoleptic desirability, aesthetic appeal and safety. To make food available throughout the year, humans have developed methods to prolong their storage life i.e. to preserve them. The rotting process can be postponed by adding preservatives, optimizing storage conditions, or applying modern techniques. Therefore, preservation of foods is imperative in order to increase their shelf life. Food preservation can result in several advantages, some of which are substantial. These include:

- increased shelf-life
- decreased hazards from microbial pathogen
- decreased spoilage (microbial, enzymatic)
- inactivation of anti-nutritional factors
- ensured round the year availability of seasonal foods
- perishable foods that can be transported to far-off distances from the site of production
- increased availability of convenience foods (e.g. Ready-to-serve beverages, Instant mixes etc.)
- increased variety of foods, some with enhanced sensory properties and nutritional attributes.

Preservation in some cases produces a different form of the products which are of great importance in various cuisines. E.g. raisins, squash and wines made from grapes.

Need for Food Preservation

When food is available more than its present use/ consumption, it should be preserved for future utilization. Thus, preservation activities ensure proper utilization of food. Preservation of fresh produce is needed for following reasons:

- For increasing availability of certain foods which have a short growing season such as fruits and vegetables, for use throughout the year.
- For utilization of surplus crops and prevent wastage.
- For saving money by preserving foods when they are most plentiful, cheaper and are of good quality.
- For producing food which is easier to store, distribute and transport and that can be made available in all places at all times.
- For meeting the needs of the people for food in secluded and difficult areas.
- For ensuring supply of protective foods in homes, hotels and other such places.

Aim of food preservation is to prevent undesirable changes in the wholesomeness, nutritive value or sensory quality of food and reduce chemical, physical and physiological changes of an objectionable nature and eliminate contamination.

The goal of food preservation is to increase the shelf life of a food while keeping it safe. It ultimately ensures its supply during times of scarcity and natural drought. The main objectives of food preservation include lengthening lag phase of bacteria growth; delaying undesired autolysis; minimizing pest/ physical damage and preventing microbial action.

Classification of foods on the basis of shelf life, pH, origin;

Classification of food on the basis of perishability (shelf life)

- Perishable foods can be stored for 1-2 days.
- Semi-perishable foods can be stored for some weeks to 1-2 months.
- Non-perishable foods can be stored longer as compared to perishables and semi-perishables.

Foods can be categorized into three main groups on the basis of their shelf life or perishability.

- **Non-perishable or stable foods:** These foods do not spoil unless they are handled carelessly. They should be stored in a cool, dry place. They can be stored for one year. They should be picked and cleaned before storage. If necessary, grains can be washed with water to remove any dust and dirt sticking to them. These should then be dried in the sun, allowed to cool and stored in containers with tight fitting lids.

Non-perishable foods include sugar, jaggery, hydrogenated fat, vegetable oil, ghee, whole grains, dais, whole nuts, dry salted fish and meat, papads, canned foods, preserves such as pickles, jams and murabbas.

- **Semi-perishable foods:** These foods do not spoil for a fairly long time if stored properly. They are more stable due to microbiological contamination and natural chemical breakdown as compared to other perishable foods.

Foods in this group can be stored for a week to a couple of months at room temperature without the development of any undesirable changes in flavour and texture.

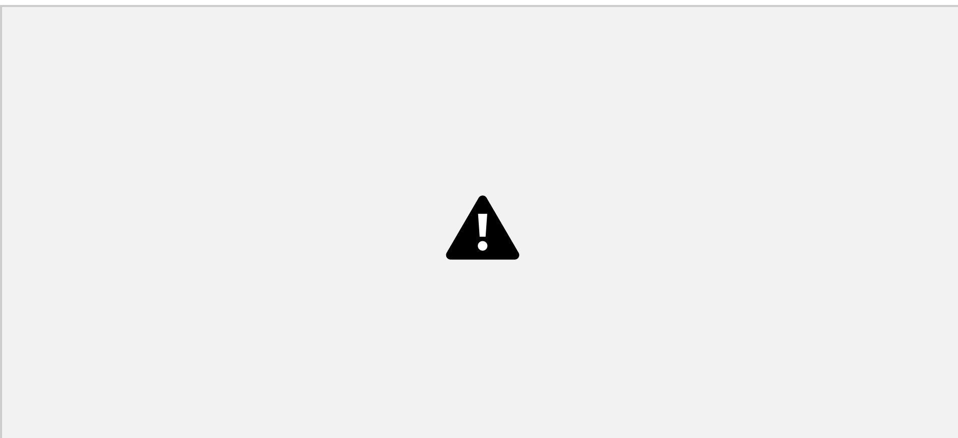
Semi perishable foods include processed cereals, pulses and their products like flour, Bengal gram flour, millet flour, semolina, parched rice, popcorn, etc. Their shelf life depends on the storage temperature and moisture in the air.

Other semi perishable foods are potatoes, onions, nuts, frozen foods kept solidly frozen at "zero" to -18°C and canned foods that need refrigeration, apples, citrus fruits, pumpkin, etc.

- **Perishable foods:** Cannot be stored for more than one or two days at room temperature, that is, they have a shelf life of 1 or 2 days. This is the largest of the three groups and includes most of the food items we consume every day, such as milk and milk products, eggs, poultry, meat, fish, most fruits and vegetables such as bananas, pineapple, papaya, green leafy vegetables, etc :

Because they contain high amounts of protein, moisture and other nutrients; they are an ideal medium for bacterial growth. They also spoil easily by natural enzymatic changes. They have a very short shelf life of a few hours to a few days, after which they spoil rapidly. Food of this group may be responsible for the food-borne illnesses.

Classification of foods on the basis of pH



Most foods are derived either from plants or from animals. pH of food is important because low acid food with a high pH (4.6 and above) are prone to contamination by clostridium botulism, which produces a toxin. Hence it is necessary to inactive this organism in such food.

- **Low acid foods**

The foods having pH above 5.3 are called low acid foods. For example: peas, corn, lima beans etc.

- **Medium acid foods**

The foods which have pH between 4.3 and 5.3 are called medium acid foods. For example: asparagus, beets, pumpkin, spinach etc.

- **Acid foods**

Foods which have pH between 3.7 and 4.5 are called acid foods. For example: pears, pineapple, tomatoes etc.

- **High acid foods**

Foods having pH 3.7 or lower are included in this category. For example: Berries and sauerkraut.

Classification of foods on the basis of origin

- Plant origin
- Animal origin

Plant origin: -

- Cereals and grasses- cereals are members of the grass family grown for their grain and most important plants eaten by men. Example-wheat, rice, corn, sorghum etc. principle source of carbohydrate although they contain protein, fats, some vitamins and minerals also. Cereals contain a good amount of thiamin and niacin.
- Legumes- they are second to the cereals as an important source of human food. They are the meat of the vegetable world and are close to animal flesh in protein food value. Soya bean is one of the oldest known food plants. The seed is the richest in food value of all the vegetables consumed throughout the world. Example: - soya bean, Bengal gram, lenticels, moong dal etc.
- Nuts: - A nut is a seed, one ceiled fruit with a hard shell. Example-hazel's nuts, chestnuts, peanuts, coconut etc.

They are of three types following as: -
High protein content. Almond
High carbohydrates content. Chestnuts
High fat content. Coconut, cashew nuts, wall nuts.

- Fruit and tuber-Plant roots and modified roots are storage organs for plants and also are important for us. -carrot, beats, radish, turnips, and sweet potato.
- Vegetables-They provide a variety of taste and texture. Example- all vegetables
- Fruit- they are ripened ovaries of a flower's edible portion is usually the fleshing covering over the seeds. - fruit vegetables-pumpkin, cucumber, tomato are technical fruits but eaten as vegetables.
- Sugar and other carbohydrates food: - the carbohydrates food commonly used are cane sugar, jiggery, glucose, honey, syrup, custard powder etc. they serve mainly as a source of energy
- Condiments and spices- they are an important source of nutrients in the average diet but are used mainly for enhancing the palatability of diet. The flavor and acceptability of food preparation

Animal origin

As the name implies, products that come from animals qualify in this group. However, not all animals are part of this group. This is because some for health reasons are not suitable for human consumption. Others due to legal prohibitions.

The consumption of animals will depend on the culture of each country and region. For example, in Asian countries it is common to eat reptile animals, bats, ants, rats, among others. However, in Western countries these animals are not consumed. some animal origin foods are Meat, fish, milk and milk products, animal by products, liver

Different types of food spoilage viz. microbiological, bio-chemical, chemical, and physical and their effects on food quality.

There are mainly three types of causes of food spoilage viz. biological, chemical and physical causes. Biological causes consist of growth and activity of microorganisms such as bacteria, yeast and moulds; activity of food enzymes and damage due to pests, insects and rodents etc. Chemical causes include reaction with oxygen and light and chemical reactions within food constituents. Physical causes consist of temperature and physical abuse.

All of these factors can act together. For example, bacteria, insects, and light, all can be operating concurrently to spoil food in a field or in a warehouse. Similarly, heat, moisture, and air at the same time affect the multiplication and activities of bacteria and chemical activities of food enzymes.

The major types of spoilage that occur in foods are due to microbiological, biochemical, physical and chemical changes. These include:

- Growth and activity of microorganisms such as bacteria, yeast and molds
- Activities of food enzymes, present in all raw foods, promote chemical reactions within the food affecting especially the food colour, texture and flavor
- Inappropriate holding temperatures (heat and cold) for a given food
- Gain or loss of moisture
- Reaction with oxygen and light causing rancidity and colour changes due to oxidative reactions
- Physical stress or abuse
- Damage due to pests, insects and rodents etc.
- Non-enzymatic reactions in food such as oxidation and mechanical damage

1. Spoilage Due to Chemical Reactions-

Chemical reactions take place in the presence of atmospheric oxygen and sunlight. Two major chemical changes, which occur during the processing and storage of fruits and vegetables, are lipid oxidation and non-enzymatic browning which deteriorate sensory quality, color and flavor.

○ Lipid oxidation is influenced by light, oxygen, high temperature and the presence of iron and copper, and water activity.

○ Non-enzymatic browning is one of the major causes of deterioration which takes place during frying, cooking, storage of dried and concentrated foods through Maillard, caramelization and ascorbic acid oxidation.

○ **Maillard reaction** occurs due to reactions between reducing sugars and amino acids in the presence of heat and results in formation of black brown insoluble pigments.

○ **Caramelization** of sugars occurs in the presence of high heat and low moisture content in the food.

○ **Oxidation of fatty acids** to other chemicals like aldehydes, ketones, alcohols and esters also results in off-flavors

2. Spoilage due to biochemical-

Different biochemical reactions in foods and plants tissues are catalyzed by enzymes. Enzymes are complex chemical substances, which are present in all living organisms and tissues, which control essential metabolic processes. Enzymatic spoilage is the greatest cause of food deterioration. They are responsible for certain undesirable or desirable changes in fruits, vegetables and other foods. Examples involving endogenous enzymes include:

- the post-harvest senescence and spoilage of fruit and vegetables;
- Oxidation of phenols in plant tissues to ortho quinones by phenolases, peroxidases and polyphenol oxidases (PPO). These ortho quinones rapidly polymerize to form brown pigments known as melanin leading to enzymatic browning;

- sugar – starch conversion in plant tissues by amylases;
- Post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).

Factors Affecting Enzymatic Activity
Factors responsible for controlling enzymatic activities are temperature, water activity, pH and chemicals which can inhibit or enhance enzyme activity.
Enzymes can act between 0°C and 60°C but 37°C is optimum temperature. Enzymes can be permanently inactivated by heat. It has been seen that for each 10°C rise in temperature, the activity of microorganisms and enzymes increases by at least twice, in the range 0-60°C. Above this, heat quickly destroys enzymes and stops living cells from working. All enzymes are inactivated at 80°C. Decreased temperatures therefore work by slowing down these changes.

3. Spoilage Due to Physical Factor-

Physical factors such as temperature, moisture and pressure can also cause food spoilage. Physico-chemical reactions are caused by freezing, burning, drying and bruising of fruits and vegetables during storage, handling and transportation, which result in food deteriorations. Food processing or storage causes some deterioration in the colour of fruits and vegetables due to the degradation of the chlorophyll resulting in dull olive-brown colour. Dehydrated green peas and beans packed in glass containers undergo photo-oxidation and loss of desirable colour occurs. Freezer induced damage observed in frozen foods affects its quality. Anthocyanins, the pigment in fresh and processed foods, form complexes with metals resulting in the change in colour. E.g. Red sour cherries react with tin and form undesirable purple complexes. Carotenoid, another colour pigment, degrades by oxidation in the presence of oxygen, light and heat.

Spoilage Due to Insects, Pests and Rodents
The main categories of foods subject to insects and pest attack are fruits, vegetables, grains and their processed products. Warm humid environments promote insect growth, although most insects will not breed if the temperature exceeds above 35°C or falls below 10°C. Many insects cannot reproduce satisfactorily unless the moisture content of their food is greater than 11 per cent.
The presence of insects and pests and their excreta in foods may render consumable loss in the nutritional quality, production of off-flavours and acceleration of decay processes due to creation of higher temperatures and moisture levels and release of enzymes. The products of insect and pests activities such as webbing, clumped-together food particles and holes can also reduce the food values.
Rats and mice carry disease-producing microorganisms on their feet and/or in their feces and urine and contaminate the food by their presence.

4. Factors Affecting Growth of Microorganism-

Most significant deteriorative changes occur in foods due to microorganisms present in air, soil, water and on foods. They use our food supply as a source of nutrients for their own growth, which results in deterioration of food and renders our food supply unfit for consumption. Microbes spoil any food in many ways viz. by increasing their number; by utilizing nutrients; by producing enzymatic changes; by contributing off-flavours; by breakdown of a product; and by synthesis of new compounds. The three major types of microorganisms which cause food spoilage are bacteria, yeasts and moulds.

Type of change	Nutritional quality related changes in food
Microbiological	Growth or presence of toxicologic and/or infective microorganisms
Enzymatic	1. Hydrolytic reactions catalyzed by lipases, proteases, etc. 2. Lipoxygenase activity
Chemical	1. Oxidative rancidity 2. Non-enzymatic browning 3. Nutrient losses

Principles of Food Preservation

All food preservation methods are based upon the general principle of preventing or retarding the causes of spoilage caused by microbial decomposition, enzymatic and non-enzymatic reactions, chemical or oxidative reactions and damage from mechanical causes, insects and rodents etc. Food preservation operates according to three principles, namely:

Prevention or delay of microbial decomposition brought out by

1. **Keeping out microorganisms or asepsis-** Asepsis refers to keeping out the micro-organisms from the food by making use of either natural covering or providing artificial covering around the food. Natural barriers in foods include outer shell of the nuts (almond, walnut, pecan nut) skin/peel of fruit and vegetables (banana, mango, citrus, ash gourd etc), shells on eggs, skin or fat in meat, husk of ear corn etc. Similarly packaging prevents entry of microorganisms in the food.
For example peach or mushroom sealed in tin cans, clean vessels under hygienic surroundings helps in preventing spoilage of milk during collection and processing by keeping out the micro-organisms.
2. **Removal of microorganisms e.g. washing, filtration etc.-** Filtration of liquid foods through bacteria proof filters is a common method for complete removal of microorganisms from the foods. Liquid foods are passed through the filters made of suitable material like asbestos pad, diatomaceous earth, unglazed porcelain etc and allowed to percolate through either with or without nano-filtration etc works on this principle.
3. **Hindering the growth and activity of microorganisms by controlling the conditions** required for the growth and activity of microorganisms by use of low temperature, drying, maintenance of anaerobic conditions or chemicals
4. **Killing microorganisms by heat or irradiation**

Prevention or delay of self-decomposition of foods by

1. **By destruction or inactivation of food enzymes (blanching or boiling):** Blanching is a mild heat treatment given to vegetables before canning, freezing or drying to prevent self decomposition of food by destroying enzymes. Blanching is carried out by dipping the food commodity either in boiling water or by exposing it to steam for a few minutes followed by immediate cooling.

2. **By prevention or delay of purely chemical reactions (use of antioxidants to prevent oxidation):** Foods containing oils and fat turn rancid and become unfit for consumption due to oxidation. Addition of appropriate quantity of antioxidants like butyl hydroxy anisole (BHA), butyl hydroxyl toluene (BHT), tertiary butyl hydroxy quinone (TBHQ), lecithin etc prevents oxidation and preserves the food.

Prevention of damage because of external factors such as insects, rodents, dust, odour, fumes, and mechanical, fire, heat or water damage.

Use of fumigants in dried fruits, cereals etc checks the damage caused by insects and rodents. Wrapping of fruits, providing cushioning trays, using light packs and good packaging material checks the damage to fresh food commodities during handling and transportation.
Eg. Use of boxes, cartons, and shock absorbing materials, sealed tight, vacuum-packaging etc.

Preservation of food by adding preservative (Class-I and Class-II)

Definition, types, Class I and Class II preservatives; Introduction, permissible limit and mode of action of sugar, salt, vinegar, benzoic acid, sulphur dioxide and sulphites, nitrates and nitrites, sorbic acid

Definition:

A preservative is defined as any substance which is capable of inhibiting, retarding or arresting the growth of microorganisms of any deterioration of food due to microorganisms, or of marking the evidence of any such deterioration.

The inhibitory action of preservatives is due to their interfering with the mechanism of cell division, permeability of cell membrane and activity of enzymes. Pasteurized squashes, cordials and crushes have a cooked flavor. After the container is opened, they ferment and spoil within a short period, particularly in a tropical climate. To avoid this, it is necessary to use chemical preservatives.

Chemically preserved squashes and crushes can be kept for a fairly long time even after opening the seal of the bottle. The preservative used should not be injurious to health and should be non-irritant. It should be easy to detect and estimate.

According to Prevention of Food Adulteration (PFA) Act (1954) and Food Standards and Safety Act (FSSA) of 2006, a 'preservative' means a substance which when added to food, is capable of inhibiting, retarding or arresting the process of fermentation, acidification or other decomposition of food.

Preservatives may be antimicrobial preservatives, which inhibit the growth of bacteria and fungi, or antioxidants such as oxygen absorbers, which inhibit the oxidation of food constituents. Common antimicrobial preservatives include calcium propionate, sodium nitrate, sodium nitrite and sulfites (sulfur dioxide, sodium bisulphite, potassium hydrogen sulphite, etc.) and ethylenediamine tetra acetic acid (EDTA). Antioxidants include butylated hydroxy anisole (BHA) and butylated hydroxytoluene (BHT).

Sulphur dioxide (including sulphites) and benzoic acid (including benzoates) are among the principle preservatives used in the food processing industry.

Under PFA (1954) and FSSA (2006), preservatives are classified into two classes Class I and Class II preservatives

Classification of food preservatives:

Class-I preservatives (Natural Preservatives)	Class-II preservatives (Artificial Preservatives)
Naturally occurring substances, generally used in kitchen	Man-made chemical substance
No restriction or limitation on use as naturally occurring	Used in limited quantity
No need to be cautious in using them, so better to choose product containing these type of preservatives	Risk in use as they are chemicals
includes salt, vinegar, vegetable oil, honey, sugar and wood smoke	Sorbic acid- sodium, potassium & calcium salts, Nisin, Benzoic acid, Nitrates / nitrites

As Class 1 preservatives are natural, there is no need to be cautious while using it. On the other hand, some risk is involved when using Class II preservatives as they are chemicals. Example, in respect of foods like ham, pickled meat,

Permissible limits of Class II preservatives in food products

Chemical preservative	**Concentration (ppm)**	**Foods**
Sorbic acid and its salts (calculated as sorbic acid)	50	Nectars, ready to serve beverages in bottles/pouches selling through dispenser
	100	Fruit juice concentrates with preservatives for conversion in juices, nectars for ready to serve beverages in bottles/ pouches selling through dispensers
	200	Fruit juices (tin , bottles or pouches)
	500	Jams, jellies, marmalades, preserve, crystallized glazed or candied fruits including candied peels fruit bars
Benzoic acid and its salts	120	Ready to serve beverages
	200	Jam , marmalade, preserve canned cherry and fruit jelly
	250	Pickles and chutneys made from fruits or vegetables
	600	Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets
	750	Tomato and other sauces; Tomato puree and paste
Sulphur dioxide	40	Jam , marmalade, preserve canned cherry and fruit jelly
	150	Crystallized glace or cured fruit (including candied peel)
	350	Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets; Fruit and fruit pulp
	2000	Dehydrated vegetables
Sodium and/ or Potassium nitrite expressed as Sodium nitrite	200	Pickled meat
Lactic acid	No limit	Fermented meat, dairy and vegetable products, sauces and dressings, drinks.
Citric acid	No limit	Fruit juices; jams; other sugar preserves
Acetic acid	No limit	Vegetable pickles; other vegetable sauces, chutney

Class-I Preservative /Natural preservatives:

Sodium chloride

Salts stop the growth of microorganisms and interfere with the action of proteolytic enzymes. Salts also cause food dehydration by drawing out water from the tissue cells. Salt is employed to control microbial population in foods such as butter, cheese, cabbage, olives, cucumbers, meat, fish and bread.

The amount of salt added determines the extent of protection afforded to the food. In the preservative action of NaCl, there is synergistic action with other intrinsic factors such as PH or extrinsic factors such as temperature, partial pressure of oxygen etc.,

Preservation by salt

Salt at a concentration of 15 to 25 per cent is sufficient to preserve most products. It inhibits enzymatic browning (interfere with the action of proteolytic enzymes) and discoloration and also acts as an antioxidant. Salts also cause food dehydration by drawing out water from the tissue cells. Salt in the form of brine is used for canning and pickling of vegetables which contain very little sugar and hence sufficient lactic acid cannot be formed by fermentation to act as preservative. It exerts its preservative action by

- Causing high osmotic pressure resulting in the plasmolysis of microbial cells.
- Dehydrating food as well as microorganisms by drawing out and tying up the moisture by ion hydration.
- Ionizing to yield the chloride ion which is harmful to microorganisms.
- Reducing the solubility of oxygen in water, sensitizing the cells against carbon dioxide, and interfering with the action of proteolytic enzymes.

Salt is employed to control microbial population in foods such as butter, cheese, cabbage, olives, cucumbers, meat, fish and bread.

Sugar:

Sugar acid in the preservation of products in which it is used. The high osmotic pressure of sugar creates conditions that are unfavorable for the growth and reproduction of most species of bacteria, yeasts and moulds. The preservative action of moderate strength of sugar can be improved if invertase is used to increase the concentration of glucose relative to sucrose.

Foods in which sugars aid preservation include syrups and confectionary products, fondant fillings in chocolate, honey, jellies, marmalades, conserves and fruits such as dates, sultanas and currants.

Preservation by Sugar

Sugar in high concentrations acts as a preservative due to osmosis. Sugar attracts all available water and water is transferred from the microorganisms into the concentrated sugar syrup. The microflora is dehydrated and cannot multiply further.

The concentration of sugar in sugar preserved products must be 68 per cent or more, which does not allow microorganisms to grow. Lower concentrations may be effective but for short duration unless the foods contain acid or they are refrigerated. The critical concentration of sugar required to prevent microbial growth varies with the type of microorganisms and the presence of other food constituents.

Some of the most popular preserves with sugar are jelly, jam and marmalade. These are the stable gels. Pectin, a natural component of fruits, forms a gel only in the presence of sugar and acid. Sugar prevents spoilage of jams, jellies, and preserves even after the container is opened.

With the use of sugar, the water activity cannot be reduced below 0.845. This level of water activity is sufficient to inhibit mesophilic bacteria and yeast but does not check mold attack. Due to this, various other methods are also adopted to prevent mold development in sugar preserved products like finished product pasteurization (jams, jellies, etc.) and use of chemical preservatives in order to obtain the antiseptisation of the product surface.

Most of these products are made of acid fruits. When foods low in acid are used, they are usually combined with some acid fruit. Besides contributing flavor to the product, the acid aids in the preservation. The amount of sugar used in manufacture of these products varies widely.

Vinegar (4% Acetic acid):

Acetic acid (CH_3COOH), in the form of vinegar, has been used to preserve pickled vegetables from antiquity. Acetates of sodium, potassium and calcium, are used in bread and other baked foods to prevent ropiness and the growth of moulds, but they do not interfere with yeasts.

The acid is also used in foods, such as mayonnaise and pickles, primarily for flavor but these products also benefit from the concurrent anti-microbial action.

The antimicrobial activity of acetic acid increases as the pH decreases. Vinegar is also a good disinfectant against Salmonella, Listeria and Staphylococcus. E. coli can tolerate a much more acidic environment than other organisms, but vinegar can be effective against it as well.

Class-II Preservative /Chemical preservatives: benzoic acid, sulphur dioxide and sulphites, nitrates and nitrites, sorbic acid

Benzoic acid

Benzoic acid is widely used as an antimicrobial agent. Its sodium salt is more soluble in water than the free acid and hence it is generally used. Sodium benzoate is nearly 170 times as soluble as benzoic acid; pure sodium benzoate is tasteless and odourless. The antibacterial action of benzoic acid is increased in the presence of Co_2 and acid e.g.*Bacillus subtilis* cannot survive in benzoic acid solution in the presence of Co_2. Benzoic acid is more effective against yeasts than against moulds. It does not stop lactic acid and acetic acid fermentation. The quantity of benzoic acid required depends on the nature of the product to be preserved, particularly its acidity. In case of juices having a pH of 3.5-4.0, which is the range of a majority of fruit juices, addition of 0.06 to 0.10% of sodium benzoate has been found to be sufficient. In case of less acid juices such as grape juice at least 0.3% is necessary.

According to FPO its permitted level in RTS and nectar is 100 ppm and in squash, crush and cordial 600 ppm. In the long run benzoic acid may darken the product. It is, therefore, mostly used in colored products of tomato, jamun, pomegranate, plum, watermelon, strawberry, coloured grapes etc.

It cannot be used for juices which are to be packed in tin containers because it not only corrodes the tin causing pinholes, but also forms H_2S which has a disagreeable smell and reacts with the iron of the tin container to form a black compound, both of which are highly undesirable.

Sulphur Dioxide

It is used in the treatment of fruits and vegetables before & after dehydration to extend the storage life of fresh grapes, prevents the growth of undesirable microorganisms during wine making, and in the manufacture of fruit juices. It has good preserving action against bacteria and moulds and inhibits enzymes, etc.

Sulphur dioxide is also the most useful agent for the prevention of browning reactions in dried fruits and prevents enzymatic browning in most cut fruits. In addition, it acts as an antioxidant and bleaching agent. These properties help in the retention of ascorbic acid, carotene and other oxidizable compounds. It is generally used in the form of its salts such as sulphite, bisulphate and metabisulphite.

Potassium metabisulphite ($K_2O_2So_2$ (or) $K_2S_2O_5$) is commonly used as a stable source of So_2. It is fairly stable in neutral (or) alkaline media. When added to fruit juice (or) squash it reacts with the acid in the juice forming the potassium salt and So_2 which is liberated and forms sulfurous acid with the water of the juice.

SO_2 has a better preservative action than sodium benzoate against bacteria and moulds. It also retards the development of yeasts in juice, but cannot arrest their multiplication, once their number has reached a high value.

So_2 gives a slight taste and colour to freshly prepared beverages but these are not serious defects if the beverage is diluted before drinking. The toxicity of So_2 increases at high temperatures. Hence its effectiveness depends on the acidity, pH, temperature and substances present in fruit juice.

According to FPO, the maximum amount of So_2 allowed in fruit juice is 700 ppm, in squash, crush and cordial 350 ppm and in RTS and nectar 100 ppm.

Advantages of using So_2 are

- It has a better preserving action than sodium benzoate against bacterial fermentation.
- It helps to retain the colour of the beverage for a longer time than sodium benzoate.
- being a gas, it helps in preserving the surface layer of juices also.
- Being highly soluble in juices and squashes, it ensures better mixing and hence their preservation any excess of So_2 present can be removed either by heating the juice to about 71^oC or by passing air through it or by subjecting the juice to vacuum. This causes some loss of the flavoring materials due to volatilization, which can be compensated by adding flavours.

Disadvantages of using So_2 are

It cannot be used in the case of some naturally colored juices like those of jamun, pomegranate, strawberry, coloured grapes, plum etc. on account of its bleaching action.

Sorbic acid:

Sorbic acid and related compounds have antimicrobial properties. They are available as sorbic acid, potassium sorbate, sodium sorbate or calcium sorbate. Salts of sorbic acid are used in many cases as they are highly soluble in water and produce sorbic acid when dissolved in water. The potassium salt of sorbic acid i.e. potassium sorbate is much more soluble in water than the acid. It does not impart any noticeable flavour at normal usage concentrations. Maximum level allowable by PFA act is 0.3 per cent. It is effective up to pH 6.5 but effectiveness increases as the pH decreases. It has about 74 per cent of the antimicrobial activity of the sorbic acid, thus it is required in higher concentrations than pure sorbic acid. It is effective against yeasts, moulds, and select bacteria, and is widely used at 0.025 to 0.10 per cent levels in cheese, beverages, fermented and acidified vegetables, smoked and salted fish. In wine processing, sorbates are used to prevent refermentation.

Nitrites and Nitrates. ($NaNO_2$ and $NaNO_3$)

Nitrites have been used in meat curing for many centuries. It is used along with a mixture of salt, sugar, spices, and ascorbate for curing meats. Nitrite contributes to the development of the characteristic colour, flavour and texture improvement in addition to preservative effects. Sodium nitrite is quite soluble in water and is more effective below neutral pH (below 7.0). Along with salt, nitrite exhibits stronger antimicrobial action.

Nitrates break down in the body to nitrites and this stops the growth of bacteria, especially Clostridium botulinum, the bacteria that cause botulism poisoning. This is the reason nitrites and nitrates are used mainly among the packaged meats.

Nitrites also stabilize the red colour in cured meat and stop it from turning gray. Nitrates get readily converted into nitrites, which then react with the protein myoglobin to form nitric oxide myoglobin. During cooking, this is converted to nitroso hemochrome, a stable pink pigment, which impart a pink, fresh hue to cured meat. This chemical stabilizes the red colour of the meat and gives an appearance of fresh meat. That is why nitrites are a preferred preservative of meat processors even though its excess use is restricted in many countries.

Nitrite salts should be used with precaution because they can react with certain amines in food at acidic pH to produce nitrosamines, which are known to cause cancer by giving rise to compounds like nitro dimethyl-amine. Addition of sodium ascorbate inhibits nitrosamine formation and reduces the problem of nitrosamines. Nitrites and nitrates are permitted as preservatives in cured meat and meat products including poultry at levels below 200 ppm by USFDA and FSSA in India.

Nitrates or nitrites are added as a preservative, antimicrobial agent or colour fixative to processed foods such as meats and cheese. It also contributes to flavor. Nitrite is added in the food as an antioxidant. Nitrate also occurs naturally in water, vegetables and plants. Nitrite when added in the food as a preservative they combine with ferredoxin of the microorganism so the action of this protein stopped and due to which ATP synthesis stopped in the microbial cell. The human body converts nitrate in food into nitrite. Nitrite has been implicated in a variety of long term health effects, including gastric cancer.

Harmful effects of Synthetic Preservatives on Health

Class II preservatives, the synthetically manufactured ones, can sometimes cause adverse reactions in humans. Here are 6 chemical preservatives that you may not want to consume.

1. **Sulfites** are often found in wines and dried fruits. They can cause allergies, asthma, headaches and other severe allergies. They also destroy B1.
2. **Nitrates** are found meats and cheeses, but are also found in fertilizers and rodent poison. High levels of nitrate consumption have been linked to cancer, brain tumors, leukemia and Blue Baby Syndrome.
3. **Sodium Benzoate** is used to preserve soda, juice, pickles, salsa and cosmetics. It is linked to hyperactivity in children and when combined with Vitamin C it becomes a carcinogen. This chemical occurs naturally in very small amounts in some fruits.

4. **BHA and BHT** are found in fats, oils, snacks, cereals, and instant potatoes. These are known to be Vitamin K antagonists, impair blood clotting in animals, cause tumors in the forestomach and liver of animals and is considered a tumor promoter. Fat tissues absorb and accumulate BHT and has been seen to cause "abnornal cellular behavior and increased liver weights" .
5. **Tertiary butyl hydroquinone (TBHQ)** is added to vegetable oils and some animal fats. Consuming high amounts of the preservative can cause nausea, vomiting, dizziness, and hyperactivity in children.

INTERMEDIATE-MOISTURE FOODS (IMF)

Intermediate moisture foods (IMF) are shelf-stable products that have water activities of 0.6-0.84, with a moisture content ranging from 15% - 40% and are edible without rehydration. These food products are below the minimum water activity for most bacteria (0.90), but are susceptible to yeast and mold growth. Traditional intermediate moisture foods (IMF) can be regarded as one of the oldest foods preserved by man. The mixing of ingredients to achieve a given aw, that allowed safe storage while maintaining enough water for palatability, was only done, however, on an empirical basis. The work done by food scientists approximately three decades ago, in the search for convenient stable products through removal of water, resulted in the so-called modern intermediate moisture foods. These foods rely heavily on the addition of humectants and preservatives to prevent or reduce the growth of microorganisms. Since then, this category of products has been subjected to continuous revision and discussion.

Definitions of IMF in terms of aw values and moisture content vary within wide limits (0.6-0.90 aw, 10-50% moisture), and the addition of preservatives provides the margin of safety against spoilage organisms tolerant to low aw. Of the food poisoning bacteria, *Staphylococcus aureus* is one of the organisms of high concern since it has been reported to tolerate aw as low as 0.83-0.86 under aerobic conditions. Many of the considerations on the significance of microorganisms in IMF are made in terms of aw limits for growth

Advantages and disadvantages of IMF preservation

Advantages:
Intermediate moisture foods have an aw range of 0.65-0.90, and thus water activity is their primary hurdle to achieving microbial stability and safety. IMF foods are easy to prepare and store without refrigeration. They are energy efficient and relatively cheap. They are not readily subject to spoilage, even if packages have

been damaged prior to opening, as with thermostabilized foods, because of low aw. This is a plus for many developing countries, especially those in tropical climates with inadequate infrastructure for processing and storage, and offers marketing advantages for consumers all over the world.

Disadvantages:
Some IMF foods contain high levels of additives (i.e., nitrites, sulfites, humectants, etc.) that may cause health concerns and possible legal problems. High sugar content is also a concern because of the high calorific intake. Therefore, efforts are been made to improve the quality of such foods by decreasing sugar and salt addition, as well as by increasing the moisture content and aw, but without sacrificing the microbial stability and safety of products if stored without refrigeration. This may be achieved by an intelligent application of hurdles (Leistner, 1994).

Fruit products from intermediate moisture foods (IMF) appear to have potential markets. However, application of this technology to produce stable products at ambient temperature is limited by the high concentration of solutes required to reduce water activities to safe levels. This usually affects the sensory properties of the food.

a_w concept

The concept of a_w has been very useful in food preservation and on that basis many processes could be successfully adapted and new products designed. Water has been called the universal solvent as it is a requirement for growth, metabolism, and support of many chemical reactions occurring in food products. Free water in fruit or vegetables is the water available for chemical reactions, to support microbial growth, and to act as a transporting medium for compounds. In the bound state, water is not available to participate in these reactions as it is bound by water soluble compounds such as sugar, salt, gums, etc. (osmotic binding), and by the surface effect of the substrate (matrix binding). These water-binding effects reduce the vapour pressure of the food substrate according to Raoult's Law. Comparing this vapour pressure with that of pure water (at the same temperature) results in a ratio called water activity (a_w). Pure water has an a_w of 1, one molal solution of sugar - 0.98, and one molal solution of sodium chloride - 0.9669. A saturated solution of sodium chloride has a water activity of 0.755. This same NaCl solution in a closed container will develop an equilibrium relative humidity (ERH) in a head space of 75.5%. A relationship therefore exists between ERH and a_w since both are based on vapour pressure.
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FRUIT JAM

Jam: Jam is prepared by boiling whole fruit pulp with cane sugar (sucrose) to a moderately thick consistency without retaining the shape of the fruit. As per FPO specification 45 parts of fruit to each 55 parts of sugar and contain 0.5-0.6% acid and invert sugar should not be more than 40%. is used for preparation of jam.

Or

Jam is a product with reasonably thick consistency, firm enough to hold the fruit tissues in position, and is made by boiling fruit pulp with sufficient sugar.

Ingredients and their roles

Fruit gives the product its special flavor and provides pectin for thickening.

Pectin provides thickening or gel formation.

- All fruits contain some pectin.
- Apples, crabapples, gooseberries, some plums, highbush cranberries and citrus peel contain large amounts of pectin.
- Fruits like blueberries, strawberries, cherries or huckleberries contain little pectin. You can make thicker products with these fruits by combining them with fruit rich in pectin or with powdered or liquid pectin.

Acid must be present to form gel in marmalades and thickening in jams, preserves and conserves.

- For fruits lacking in natural acid, like strawberries, recipes call for lemon juice or other citrus fruit.
- Commercial pectin products contain organic acids that increase the acid content of fruits.

Sugar aids in gel formation, develops flavor by adding sweetness, and acts as a preservative.

- Corn syrup or honey can replace half of the sugar in a recipe.
- Use light colored, mild-flavored honey; too much honey can overpower the fruit flavor.

Preparation of Jam

Jam can be prepared from one kind of fruit or from two or more kinds. It may be made from practically all varieties of fruit. Apple, papaya, carrot, strawberry, mango, grapes, pineapple, etc. are used for the preparation of jams. Various combinations of different varieties of fruit can be often made to advantage, pineapple being one of the best for blending purposes because of its pronounced flavour and acidity.

Selection of fruit: Fruit should be in the right proportion which gives a good quantity of pectin and also natural flavour. For this fully ripped and ripped fruit are used in the right proportion.

Preparation of fruit pulp: Sound fruit is sorted, washed in running water or, preferably, brush-washed and prepared. The mode of preparation varies with the nature of the fruit. For example, mangoes are peeled, steamed and pulped; apples are peeled, cored, sliced, heated with water and pulped; plums are scalded and pulped; peaches are peeled and pulped; apricots are halved, steamed and pulped; berries are heated with water and pulped or cooked as such.

Addition of sugar: To make jams and jellies, up to a maximum of 25% of corn syrup for sweetness can be utilized. Generally, cane sugar of good quality is used in the preparation of jams. The proportion of sugar to fruit varies with type and variety of fruit, its stage of ripeness and acidity. A fruit pulp to sugar ratio of 1:1 is generally followed. This ratio is usually suited to fruits viz., berries, currants, plums, apricots, pineapple and other tart fruits.

Addition of acid: Citric, malic or tartaric acids are present naturally in different fruits. These acids are also added to supplement the acidity of the fruits deficient in natural acids during jam making. Addition of acid becomes necessary as an adequate proportion of sugar- pectin- acid is required to give a good set to the jam. The recommended pH for the mixture of fruit juice and pectin is 3.1. The acidity of finished jam varies between 0.5 to 0.7 % depending on the type of the jam. It is often advisable to add acid at the end of cooking which leads to more inversion of sugar. When acid is added in the beginning, it will result in a poor set.

Processing/boiling: Fruit pulp is cooked with the requisite quantities of sugar and pectin, and finished to 69% Total Soluble Solids (TSS). Permitted food colors, requisite amount of citric acid and flavorings are added at this stage. The boiling process, in addition to excess water removal, also partially inverts the sugar, developing the flavor and texture. During jam boiling, all microorganisms are destroyed within the product. When this is filled hot into clean receptacles which are subsequently sealed, and then inverted the hot jam contacts the lid surface, thus preventing the spoilage by micro-organisms during storage.

Judging of End Point

Concentration of jam is finished at an optimum point avoiding over cooking which leads to economic losses due to less yield. But under cooking will result in the spoilage of jam during storage due to fermentation. The finishing or end point of jam can be determined by the following methods.
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Drop test: This method is the simplest way and commonly used by housewives where no other facilities are available. In this method, a little quantity of jam is taken from the boiling pan in a teaspoon and allowed to air cool before putting a drop of it in a glass filled with water. Settling down of the drop without disintegration denotes the end point

By sheet test: In this test, a small portion of jam is taken with a large spoon or wooden ladle, cooled slightly and then allowed to drop off keeping the spoon or ladle in a horizontally inclined position. If the jam drops like syrup, further concentration is needed. If it is in the form of flake or forms a sheet, the finishing point is attained

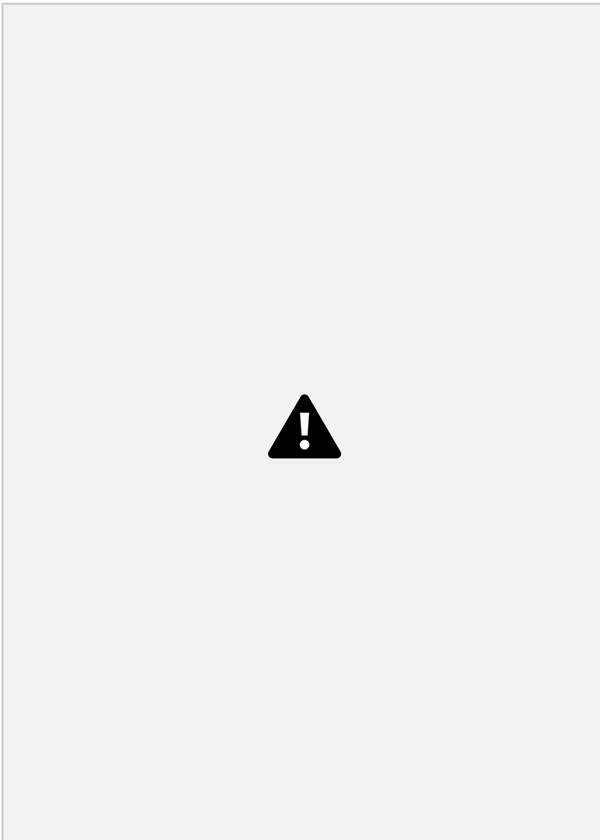
Refractometer method: This is the most common method used by small and large scale fruit processing industries for jam making. The cooking is stopped when the refractometer shows 69^{o} Brix.

Boiling point method: Jam containing 69% TSS boils at 106 $_{o}$C at sea level. This method is simplest and best to determine the finishing point of the jam.

By weighing method: Weighing method is more laborious and time consuming. Here the boiling pan is weighed before and again after transferring the extract and sugar in to it. The end point is attained

when the net jam weight is one and a half times of the quantity of sugar added.
Packaging The product is packed in cans or glass jars, and cooled, followed by labeling and packaging. Containers including can or jar gets sterilized when hot jam(not less than 85$_{o}$C) is poured in them. Boiling the containers in hot water can also affect sterilization.

Special Care/ Problems in Jam Production
Crystallization: The final product should contain 30–40% invert sugar. If the percentage is less than 30, cane sugar may crystallize out of storage and if it is more than 50 the jam will become a honey-like mass due to high inversion of 40 % sugar into glucose. Corn syrup or glucose may be added along with cane sugar to avoid crystallization.
Sticky or gummy jam: Because of the high percentage of total soluble solids, jams tend to become gummy or sticky. This problem can be solved by addition of pectin or citric acid, or both.
Premature setting: This is due to low total soluble solids and high pectin content in the jam and can be prevented by adding more sugar. If this cannot be done a small quantity of sodium bicarbonate is added to reduce the acidity and thus prevent pre-coagulation.
Surface graining and shrinkage: This is caused by evaporation of moisture during storage of jam. Storing it in a cool place can reduce it.
Microbial spoilage: The mould attack on jam can be eliminated by storing them at less than 90% RH (Preferably at 80% RH). It is also advisable to add 40 ppm sulphur dioxide in the form of KMS. In the case of cans, sulphur dioxide should not be added to the jam as it causes blackening of the internal surface of the can.



FRUIT JELLY
Jelly: Jellies are gellified products obtained by boiling fruit juices with sugar, with or without the addition of pectin and food acids.
OR
Jelly is a semi solid product prepared by boiling a clear, strained solution of pectin containing fruit extract, free from pulp, after addition of sugar and acid.

A jelly is a semisolid product prepared by boiling fruit with water, expressing as water (pectin) extract), adding sugar, and concentrating to such consistency that gelatinization takes place on cooling. A perfect jelly should be transparent, well set, but not too stiff, and should have the original flavour of the fruit. It should be of attractive colour and keep its shape when removed from the mould. It should not be gummy, sticky, or syrupy or have crystallized sugar.

Preparation of Jelly

A. ***Selection of fruits:*** Guava, sour apple, plum, papaya, certain varieties of banana and gooseberry are generally used for preparation of jelly. Other fruits can also be used but only after addition of pectin powder, since these fruits are low in pectin content. Fruits can be divided into four groups according to their pectin contents. This classification is highly useful in preparation of jelly, because pectin is the important component, which is responsible for the texture of the jelly. The classification is as follows.

- Rich in pectin and acid: sour apple, grape, lemon, sour oranges, jamun, sour plum.
- Rich in pectin but low in acid: apple, unripe banana, pear, ripe guava, etc.
- Low in pectin but rich in acid: sour apricot, sweet cherry, sour peach, pineapple and strawberry.
- Low in pectin and acid: ripe apricot, peach, pomegranate, strawberry and other over ripe fruits.

B. ***Extraction of pectin/boiling:*** After selection, the fruits are washed thoroughly. Most of the fruits are boiled for extraction of the juice in order to obtain maximum yield of juice and pectin. Boiling converts protopectin into pectin and softens fruit tissues. Very juicy fruits do not require the addition of water and are crushed and heated to boiling only for 5 min. Firm fruits are cut or crushed and boiled with water for 5 min. The length of boiling will vary according to the type and texture of fruit. The amount of water added to the fruit must be sufficient to give a high yield of pectin e.g. apples require one half to an equal volume of water, whereas citrus fruits require 2-3 volumes of water for each volume of sliced fruits.

C. ***Straining and clarification:*** Pectin extract is obtained by straining the boiled fruit mass through bags made of linen, flannel, or cheese cloth folded several times. For large scale production, the fruit extract is made to pass through filter presses for clarity.

- ***Analysis of extract:*** Clarified extract is analyzed for pH, acidity, soluble solids and pectin content by common laboratory methods.

For determining pectin content the easiest way adopted is precipitating the pectin with alcohol. A rapid test for evaluation of juice pectin content is by mixing a small sample of juice with an equal volume of 96% alcohol in a tube. The mixture from the tube is then emptied on a plate. The appearance of a compact gelatinous precipitate indicates sufficient pectin content for jellification (Figure J-1). Insufficient pectin will remain in numerous small granular lumps

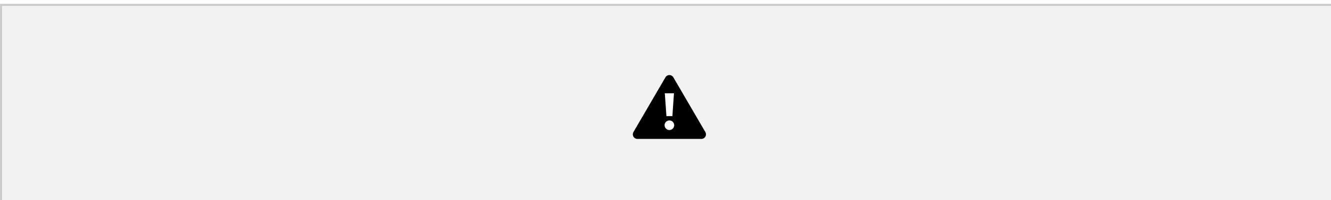
.

Figure J-1 .4: Pectin test for jelly extract. a) Low pectin extract; b) High pectin extract

D. ***Addition of sugar and pectin:*** Based on the pectin test of the fruit extract, the quantity of sugar to be added is worked out. For the extract rich in pectin, sugar equal to the quantity of the extract is added. To the extract with moderate pectin 650 – 750 g of sugar should be added to each kg of extract. For juices rich in pectin, jellification will occur without pectin addition. If pectin content is less, 1-2% powder pectin will be added to the juice.

E. ***Addition of acid:*** Jelly strength increases with increasing hydrogen ion concentration until an optimum pH is reached which is generally 3.2 at 65%sugar concentration. Jellying strength depends on the quantity of pectin and the acid present in the original fruit extract.

F. ***Processing/boiling:*** The juice is boiled up to remove about half of the water that has to be evaporated. Then the calculated sugar quantity is added gradually. The remainder of the water is evaporated until a TSS (refractometric extract) of 65% is reached. During boiling it is necessary to remove foam / scum formed. Product acidity must be brought to about 1% (malic acid) corresponding to pH > 3. Any acid addition is performed always at the end of boiling. Boiling of jellies is performed in small batches (25-75 kg) in order to avoid excessively long boiling time which brings about pectin degradation.

G. **Judging of End Point**: Boiling of jelly should not be prolonged, because excessive boiling results in greater inversion of sugar and destruction of pectin. The end point can be judged by sheet test, drop test, refractometry, thermometer, and by weighing the boiling mass. Methods like sheet test, drop test, and weighing of the boiling mass can be done in the similar way as in the case of jam preparation.

- ***Refractometer method:*** This is the most common method used in fruit processing industries for jelly making. The cooking is stopped when the refractometer shows 65°Brix.
- ***Temperature test:*** A solution containing 65% TSS boils at 105°C. Heating of the jelly to this temperature would automatically bring the concentration of solids to 65%. Endpoint of finishing jelly should be 4.5-5°C higher than that of the boiling point of water at that place.

H. **Packaging:** After jelly is ready, it is skimmed to remove foam. It is cooled slightly before pouring into dry and hot glass jars. Cooling is optional and is carried out up to 85oC, in double wall baths with water circulation. Filling is performed at a temperature not below 85oC in receptacles (glass jars, etc.), which must be maintained still for about 24 hours to allow cooling and product jellification.

Problems in Jelly Making

The most important difficulties that are experienced are as follows:

• ***Failure to set:*** This may be due to the addition of too much sugar, lack of acid or pectin, cooking below/ beyond the end-point.

• ***Color changes:*** Darkening at the top of the jars can be caused by storing them in too warm a place or by an imperfect jar seal.

• ***Gummy jelly:*** It is the result of prolonged or over cooking in which more than desired inversion of sugar occurs

• ***Stiff jelly:*** Over cooking or using too much pectin makes too tough jelly which fails to spread when applied on bread.

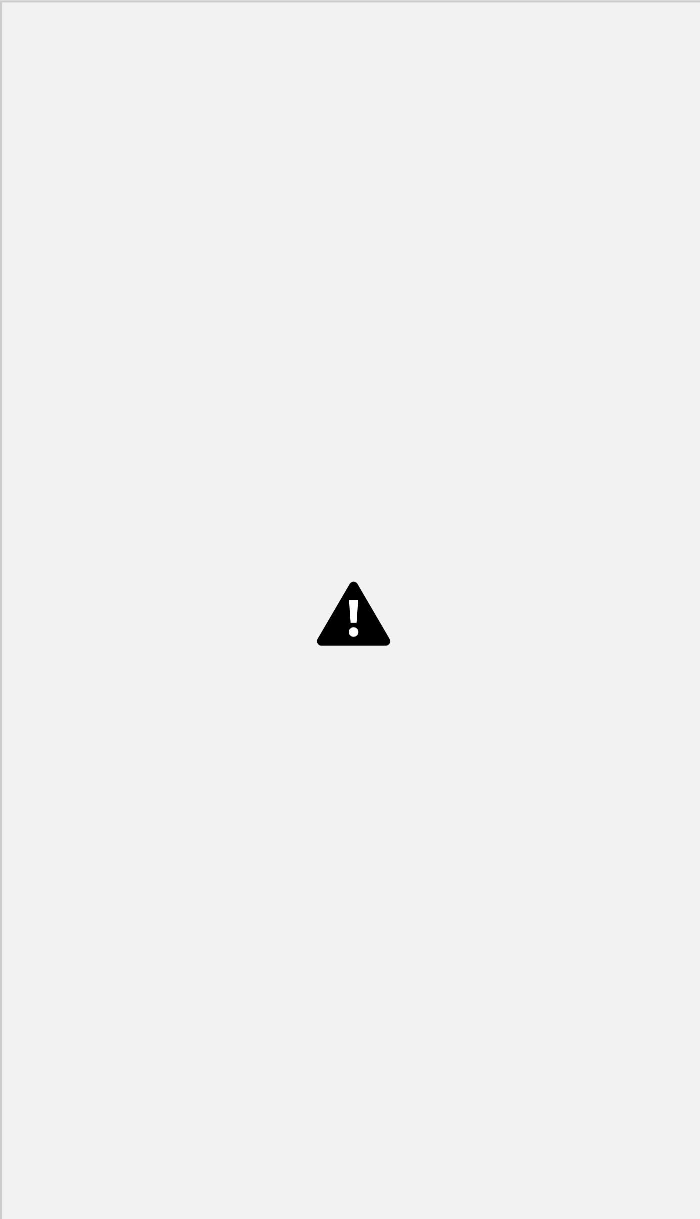
• ***Cloudy or foggy jellies:*** It is due to the use of non-clarified juice or extract, use of immature fruits, over-cooking, over-cooling, non-removal of scum, faulty pouring, and premature gelation.

• ***Formation of crystals:*** It is due to addition of excess sugar and also due to the over-concentration of jelly. This excess sugar comes from over cooking, too little acid or from under cooking.

• ***Syneresis or weeping of jelly:*** The phenomenon of exudation of fluid from a gel is called syneresis or weeping and is caused by several factors. The factors include; excess of acid, too low concentration of sugar, insufficient pectin, premature gelation, and fermentation

• ***Presence of mold:*** Due to imperfect sealing and insufficient sugar.

• ***Color fading:*** This is due to high temperature and bright light in the storage room. Another possible cause could be the insufficient processing to destroy the enzymes affecting color or the elevated processing temperature, which might cause colour fading. Trapped air bubbles can also contribute to the chemical changes by oxidation.



FLOW DIAGRAM FOR JELLY MAKING

MARMALADE

Marmalade is a fruit jelly in which slices of the fruit or its peel are suspended.
OR
Marmalade is a clear jelly in which shreds of peel are suspended. It is generally prepared from citrus fruits

Marmalade preparation is similar to jelly with the difference that it contains citrus fruits like oranges and lemons in which shredded peel is used as the suspended material. In the preparation of marmalade bitterness is regarded as a desirable characteristic of the product. The principles of jelly making, apply also to the reparation of marmalade Marmalades are classified into two:
Jelly marmalade
Jam marmalade

Jelly Marmalade

Good quality jelly marmalade can be prepared from a combination of Sweet orange/ Mandarin orange and sour orange in a 2:1 proportion. Shreds of sweet orange (Malta) peel are used in the preparation.

Selection of fruit

Sound, ripened fruit is sorted, washed, and prepared. The mode of preparation varies with the nature of the fruit. The fruits are then cut into slices and are boiled for the preparation of extract.

Extraction of pectin/boiling: After selection, the fruits are washed thoroughly. Most of the fruits are boiled for extraction of the juice in order to obtain maximum yield of juice and pectin. Boiling converts protopectin into pectin and softens fruit tissues. The amount of water added to the fruit must be sufficient to give a high yield of pectin e.g. apples require one half to an equal volume of water, whereas citrus fruits require 2-3 volumes of water for each volume of sliced fruits.

Straining and clarification: Pectin extract is obtained by straining the boiled fruit mass through bags made of linen, flannel, or cheese cloth folded several times. For large scale production, the fruit extract is made to pass through filter presses for clarity

Analysis of extract: Like Jelly.

Preparation of peel shreds: The outer layer of the yellow portion of citrus fruits is peeled off carefully. The stripped-off peel is cut into slices of about 2-2.5 cm long and 1-1.2 mm thick. Boiling in water with 0.25% sodium bicarbonate or 0.1% ammonia solution can soften the shreds. Before addition to the jelly, the shreds may be kept in heavy syrup for some time to increase their bulk density to avoid floating on the surface when it is mixed with jelly.

Addition of sugar and pectin: Based on the pectin test of the fruit extract, the quantity of sugar to be added is worked out. For the extract rich in pectin, sugar equal to the quantity of the extract is added. To the extract with moderate pectin 650 – 750 g of sugar should be added to each kg of extract. For juices rich in pectin, jellification will occur without pectin addition. If pectin content is less, 1-2% powder pectin will be added to the juice.

Addition of acid: Jelly strength increases with increasing hydrogen ion concentration until an optimum pH is reached which is generally 3.2 at 65%sugar concentration. Jellying strength depends on the quantity of pectin and the acid present in the original fruit extract.

Processing: During boiling, the impurities in the form of scum are occasionally removed. When the temperature of the mixture reaches 103$_o$C, the prepared shreds of peel are mixed in it at the rate of 5-7% of the original extract. Boiling is continued till the end point is reached. The end point is judged in the same way as in the case of jelly. Like jelly, marmalade also contains 65% TSS at 105$_o$C. Boiling should not prolong for more than 20 min, after the addition of sugar to get bright and sparkling marmalade.

Cooling: The marmalade is cooled to permit the absorption of sugar by the shreds from the surrounding syrup. If the marmalade is filled in hot, the shreds may come to the surface instead of remaining in suspension. During cooling, the product is gently stirred occasionally for uniform distribution of shreds. When marmalade temperature reaches around 85$_o$C, viscosity of syrup increases and a thin film begins to form on the surface, which prevents shreds from coming to the surface.

Flavoring: This is done by adding some flavor or orange oil to the product near the end of boiling to supplement the flavor lost during boiling. Generally, a few drops of orange oil are mixed in marmalade before filling into containers.

Packaging and Storage: Like jams and jellies, marmalade is also filled into jars and cans at a temperature around 85$_0$C. Storage of marmalade must be done in dry rooms (relative humidity at about 75%), well ventilated, medium cool places (temperature 10-20$_o$C), disinfected and away from direct sunlight and heat. These measures are necessary because marmalade is a hygroscopic product and, by water absorption, favorable conditions for mould development are created.

Jam Marmalade

Jam marmalade is practically made by the method used for preparation of jelly marmalade except that the pectin extract is not clarified. The orange peel after removing the albedo portion is sliced into 0.3 cm thick pieces and treated in the same way as recommended for jelly marmalade. The sliced fruit of orange, lemon, or grapefruit after removing peel is mixed with a little quantity of water and boiled to soften. The boiled mixture is pressed through coarse pulper to remove seed and to get thick pulp. The pulp is mixed with equal quantities of sugar and cooked to a consistency of 65^{o}Brix or consistency of jam. The treated shreds are mixed in the jam when it is slightly cool. Some orange oil is also mixed in the marmalade before filling into containers. Filling and packaging is done in the similar way as adopted for packaging of jelly and jelly marmalade.

Problems in Marmalade Making- Browning during storage is very common which can be prevented by the addition of 0.09g of potassium metabisulphite (KMS) per kg of marmalade and not using tin containers. KMS dissolved in a small quantity of water is added to the marmalade while it is cooling. KMS also eliminates the possibility of spoilage due to moulds.

PICKLES

Pickle is an edible product preserved in a solution of common salt and vinegar. It is one of the most ancient methods of preserving fruits and vegetables. Pickles are good appetizers and add to the palatability of the meal. They stimulate the flow of gastric juice and thus help in digestion. Several kinds of pickles are sold in the Indian market. Mango pickle ranks first. Pickles can also be prepared from fruits and vegetables like lemon, amla, onion, cauliflower, cabbage, beans, cucumber, bitter gourd, jackfruit, turnip etc.Fruits are generally preserved in sweetened and spiced vinegar, while vegetables in salt.

Ingredients

Salt

Use a canning or pickling salt. Non Caking material added to other salts may make the brine cloudy. Do not reduce salt in fermented pickles because proper fermentation depends on the correct proportions of salt and other ingredients. Flake salt varies in density and is not recommended for use.

Some fresh-pack pickles can be prepared safely with reduced or no salt. Use only tested recipes formulated to produce the proper acidity. Both the texture and flavor of these pickles may be noticeably different than expected. The quick pickle recipes in this publication may be made with reduced-sodium salts, such as light salts. Use of salt substitutes is not recommended.

Caution: The use of reduced-sodium salt in fermented pickle recipes is not recommended.

Vinegar

White distilled or cider vinegars of 5 percent acidity (50 grain) are recommended. White vinegar usually is preferred when light color is desirable, as for fruits and cauliflower.

Do not dilute vinegar unless the recipe so specifies. If a less sour pickle is preferred, add sugar rather than decrease vinegar.

Sugar

White granulated and brown sugars are used most often. Brown sugar gives a darker color and distinct flavor. Corn syrup and honey may alter the flavor.

Water

A soft water is recommended for pickle making. Very hard water may have an undesirable effect on the color and flavor of pickled products. However, some hard water might produce a firmer pickle.

Hard water may be softened somewhat by the following method: Boil the water for five minutes. Skim off the scum and let the water sit for 24 hours. Then ladle off the water without disturbing the sediment in the bottom. Another option is to dilute hard water with soft water. To dilute, mix one part hard water with two parts soft water.

Spices

Use fresh, whole spices for the best flavor in pickles. Powdered spices may cause the product to darken or become cloudy. Tying whole spices loosely in a cheesecloth bag, putting the bag in the pickling liquid and then removing the bag before canning is best. If desired, add individual spices, such as a cinnamon stick, from the bag to each jar. Spices deteriorate and quickly lose their pungency in heat and humidity. Store opened spices in an airtight container in a cool, dark place.

Pickling Process

The preservation of food in common salt or in vinegar is called pickling. Pickling may also be the result of fermentation by lactic acid forming bacteria, which are naturally present in large numbers on the surface of fresh vegetables and fruits. These bacteria can grow in acid medium and in the presence of 8- 10%

salt solution, whereas the growth of majority of undesirable organisms is inhibited. Lactic acid bacteria are most active at 30oC, so this temperature should be maintained, as far as possible, in the process of pickling. Pickling is done in two stages.

Stage I can be done by any of the three following methods:

i) Fermentation with dry salting,
ii) Fermentation in brine, or
iii) Salting without fermentation.

Stage II is finishing and packing.

Fermentation with Dry Salting

In this method, the vegetable is treated with dry salt. The salt extracts the juice from the vegetables and forms the brine, which is fermented by lactic acid bacteria. The method of dry salting in general is as follows:

The vegetable is washed, drained, weighed for preparing pickles.

Several alternate layers of the prepared vegetable and salt (20-30 g of dry salt/ kg vegetables) are kept in a vessel which is covered with a cloth and a wooden board and allowed to stand for 24 hrs. During this period brine is formed by osmosis. As soon as the brine is formed, the fermentation process starts and the CO_2 begins to evolve.

When fermentation is over, gas formation stops. Under favorable conditions fermentation is completed in 8-10 days, however in cold weather it may take 2 to 4 weeks. When sufficient lactic acid has been formed, lactic acid bacteria stop to grow and no further change takes place in vegetables.

Precaution should be taken against spoilage by aerobic microbes, because in the presence of air "pickles scum", a kind of wild yeast, is formed which brings about putrefaction and destroys the lactic acid.

The product may be preserved and kept by excluding air.

Fermentation in Brine

In this method steeping of the vegetables inbrine, it penetrates in the tissues of the vegetables and soluble material presentin vegetable diffuses into the brine by osmosis. The soluble material includes fermentable sugars and minerals. The sugars serve as food for lactic acidbacteria, which convert them into lactic and other acids. The acid brine thusformed acts upon vegetable tissues to produce characteristic taste and aroma ofpickle.The amount of brine required is usually half the volume of vegetables. Briningis the most important step in pickling. The growth of the majority of spoilageorganisms is inhibited by brine containing 15% salt. Lactic acid bacteria are salt-tolerant and can grow in brine of 8-10% strength. In brine containing 10% salt, fermentation precedes somewhat slowly so 5 % brine used for fair fermentation. Fermentation takes place to some extent up to 15 % but stops at 20% brine strength. After fermentation process, the salt content is now increased gradually, so that by the time pickle is ready, salt concentration reaches 15%.

Salting Without Fermentation

In this type of process vegetables are washed, prepared and is mixed with salt (250 g/kg of prepared material). This high salt concentration will inhibit the fermentation. After curing of Vegetables with large amount of salt they are drained and excess of salt is removed by soaking them in cold or warm water. Thereafter, the vegetables are stored in plain vinegar of 10% strength for several weeks. Vegetables can also be stored in sweetened and spiced vinegar. The spices can be added in the ground form or essential oil of spices may be added to impart the spice flavour.

Methods of Pickling

Pickling uses the salt combined with the acid, such as acetic acid (vinegar), oil and spices. Based on the ingredients, the pickles differ. Different methods of pickling are:

- Pickles with salt
- Pickles with vinegar
- Pickles with oil
- Pickles with salt, vinegar, oil and spices

Pickles with salt-Vegetables are usually preserved by salting. Salt content of 15 per cent or above prevents microbial spoilage as well as inhibits enzymatic browning and discoloration. Salting improves the taste and renders firmness in tissues of vegetables and controls fermentation. This method is suitable for vegetables as they contain very little sugar, as a result lactic acid is not formed in sufficient amounts to act as a preservative. However, some fruits viz. mango, lemon, etc. are also preserved with salt.

Pickles with vinegar-Vinegar pickles are the most important pickles consumed in other countries. Vinegar in concentrations up to 4 per cent acetic acid and higher concentrations has bacteriostatic and bactericidal action, respectively. The final concentration of 2-3 percent acetic acid is required to ensure preservation. For this, 6-9 per cent acetic acid vinegar is used, to overcome dilution by water oozing out of tissues. Such higher concentration helps to expel the gases present in the intercellular spaces of vegetable tissue. In vinegar pickles, salt (2-3 per cent) and sometimes sugar (2-5 per cent) are also added. If the vinegar concentration is lower than 2 per cent, vinegar pickles need to be subjected to pasteurization in order to assure their preservation. Mango, garlic, chilies, etc. are preserved in vinegar.

Pickles with oil-Highly spiced oil pickles are quite popular in India. Oils like mustard oil, rapeseed oil, sesame oil are generally used for pickling. The fruits or vegetables should be completely immersed in the edible oil. Cauliflower, lime, mango and turnip pickles are the most important oil pickles. The pickle remains in good condition for one to two years if handled properly.

Pickles with salt, vinegar, oil and spices-This method combines the advantages of fermentative action of salt and the preservation action of both vinegar and oil . The flavouring and antibacterial property of spices is also made use of in this kind of pickle. The powdered spices are usually fried in oil and mixed to the prepared fruit/ vegetable before the addition of vinegar.

VARIOUS PICKLES

At present, pickles are prepared with salt, vinegar, oil or with a combination of above ingredients with spices. These methods are discussed below:

Preservation with Salt

Salt improves the taste and flavour and hardens the tissue of vegetables and controls fermentation. Salt content of 15% or above prevents microbial spoilage. This method of preservation is generally used only for vegetables, which contains very little sugar. Since the sugar content is less, sufficient lactic acid cannot be formed by fermentation to act as preservative. However, some fruits viz., mango, lemon, etc. are also preserved with salt. An example for pickle preparation with salt is shown

Mangoes (Matured green)
↓
Washing
↓
Peeling
↓
Slicing
↓
Putting slices in jar
↓
Sprinkling salt
↓
Putting in sun for one week
(Shaking jar at least twice a day to mix the salt)
↓
Mixing spices
↓
Storage at ambient temperature (In cool dry place)

Flow chart of mango pickle

Preservation with Vinegar

This technology is based on the addition of food grade vinegar which has a bacteriostatic action in concentrations up to 4% acetic acid and bactericidal action in higher concentrations. Vegetables preserved in vinegar need to reach a final concentration of 2-3% acetic acid in order to assure their preservation.
To achieve this final concentration, 6-9% acetic acid vinegar is used, as related to the specific ratio of vinegar: vegetable. This higher concentration treatment helps to expel the gases present in the intercellular spaces of vegetable tissue.

In vinegar pickles, salt (2-3%) and sometimes sugar (2-5%) are also added. If the vinegar concentration is lower than 2%, vinegar pickles need to be submitted to pasteurization in order to assure their preservation. Mango, garlic, chilies, etc. are preserved as such in vinegar. Vinegar pickles are the most important pickles consumed in other countries.

Onion (small)
↓
Peeling
↓
Blanching for 5 minutes
↓
Filling blanched onions in jar
↓
Addition of salt
↓
Keeping for 1-2 days
↓
Draining off water
↓
Addition of vinegar and Spices
↓
Storage

Flow chart of onion pickle

Preservation with Oil

Oil pickles are highly popular in India. They are highly spiced. In India, mustard oil, rapeseed oil, sesame oil are generally used. The fruits or vegetables should be completely immersed in the edible oil. Cauliflower, lime, mango and turnip pickles are the most important oil pickles. The pickle remains in good condition for one to two years if handled properly. A schematic flow chart of lemon pickle by using oil as preservative is shown in

Lemon
↓
Washing
↓
Cutting into 4 pieces
↓
Squeezing out juice from 1/4th amount of fruit
↓
Mixing spices and salt with juice
↓
Mixing with pieces
↓
Filling in jar
↓
Keeping in sun for 4-6 days
↓
Addition of oil after heating

↓
Cooling it
↓
Storage

Flow chart of lemon pickle

Preservation with Salt, Vinegar, Oil and Spices

This method combines the advantages of fermentation action of salt and the preservation action of both vinegar and oil. The flavouring property of spices is also made use of. The spices are usually fried in oil and mixed to the prepared fruit/ vegetable before the addition of vinegar. The spices can be added separately or in the form of spice vinegar. A schematic flow chart of tomato pickle by using salt, vinegar, oil and spices as preservative is shown

Tomatoes
↓
Washing
↓
Blanching for 5 minutes
↓
Cooling immediately in water
↓
Peeling & Cutting into 4-6pieces
↓
Frying all ingredients in a little oil (except vinegar)
↓
Mixing with pieces
↓
Heating for 2 minutes & Cooling
↓
Addition of vinegar & remaining oil
↓
Filling in jars & storage

Flow chart of tomato pickle

Unit-III

Drying or dehydration

Drying is one of the oldest methods of preserving food. Today the drying of foods is still foods can be stored for long period without any deterioration in quality. The principal reasons for this are that the microorganisms, which cause food spoilage and decay, are unable to grow and multiply in the absence of sufficient water and many of the enzymes which promote undesired changes in the food cannot function without water.

Drying or dehydration is accomplished by the removal of water from the fruits and vegetables below a certain level at which enzyme activity and growth of microorganisms is affected adversely. Both term drying and dehydration mean the removal of water.

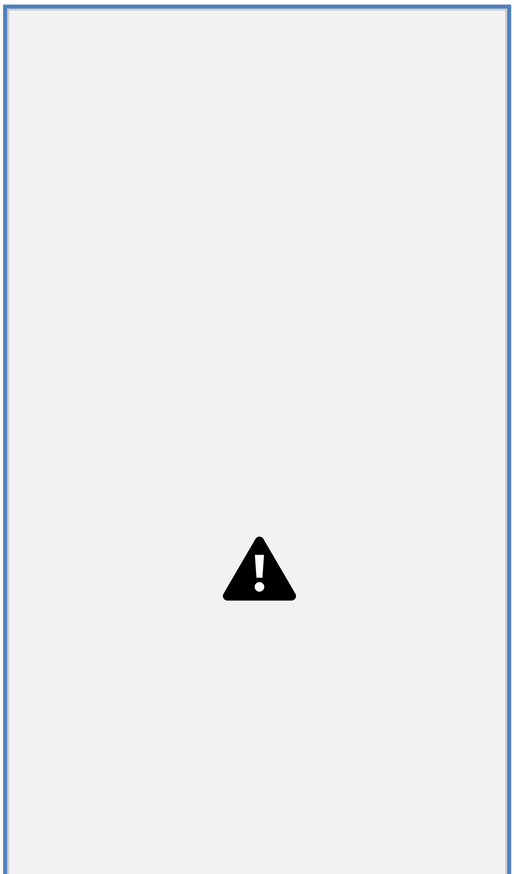
The term drying is generally used for drying of the produce under the influence of non-conventional energy sources like sun and wind.

Dehydration on the other hand refers to the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, relative humidity and air flow.
The sun drying is dependent upon the elements which are beyond the strict control. It is a slow process and thus, not suitable for many high-quality products.

Generally, it will not lower the moisture contents below about 15% which is too high for storage stability of numerous products. Removal of water from foods provides microbiological stability and assists in reducing transportation and storage costs.

PROCEDURES FOR DRYING

Drying of fruit/ vegetable involves three stages; pre-drying treatments, drying of the commodity and post drying treatments.



Raw Material Preparation (washing, Peeling, Preparation)
This includes selection of fruits, sorting, washing, peeling (for some fruits and vegetables), cutting into the appropriate form, and blanching (for some fruits and most vegetables). Fruits and vegetables are selected and sorted according to size, maturity and soundness. It is then washed to remove dust, dirt, insect matter, mould spores, plant parts and other material that might contaminate or affect the colour, aroma, or flavour of the fruit or vegetable. Peeling or removal of any undesirable parts is followed by washing. The raw product can be peeled by hand, with lye or alkali solution, with dry caustic and mild abrasion, with steam pressure, with high-pressure washers, or with flame peelers.

Blanching

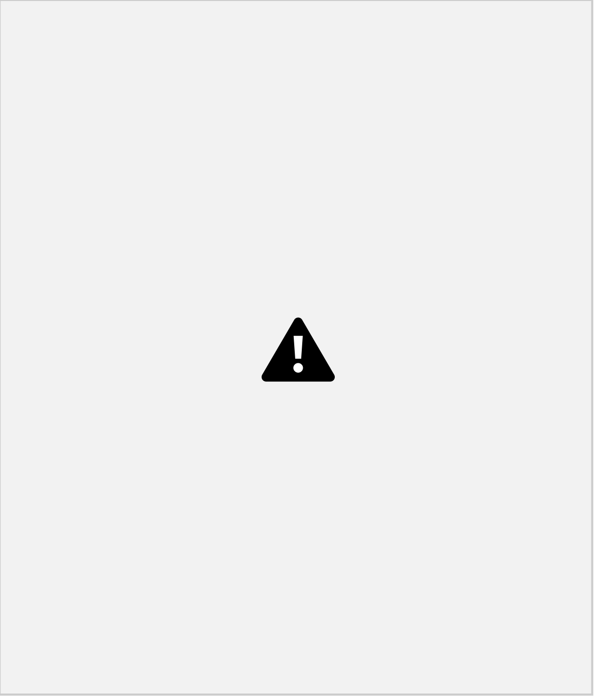
Blanching is a partial pre-cooking treatment in which vegetables/ fruits are usually heated in water or in live steam to inactivate the enzymes before processing.

Purpose of blanching

• Reduces drying time
• Removes inter- cellular air from the tissues
• Causes softening of texture
• Retards the development of objectionable odour and flavour during storage by enzyme inactivation
• Retain carotene and ascorbic acid during storage
• Removes pungency (onion)
• Impart desired translucent appearance to the product.

Spreading on flat wooden trays

After blanching spreading of fruits or vegetables on trays helps to remove excess water from the surface of raw material.



Sulphuring

The whole fruits, slices or pieces are exposed to the fumes of burning sulphur inside a closed chamber known as sulphur box for 30-60 minutes.

Purpose of Sulphuring

• Prevent oxidation and darkening
• Act as preservative/ antimicrobial agents
• Check the growth of moulds
• Prevent cut fruits from fermentation
• Prevent the vitamin losses

Drying/Dehydration

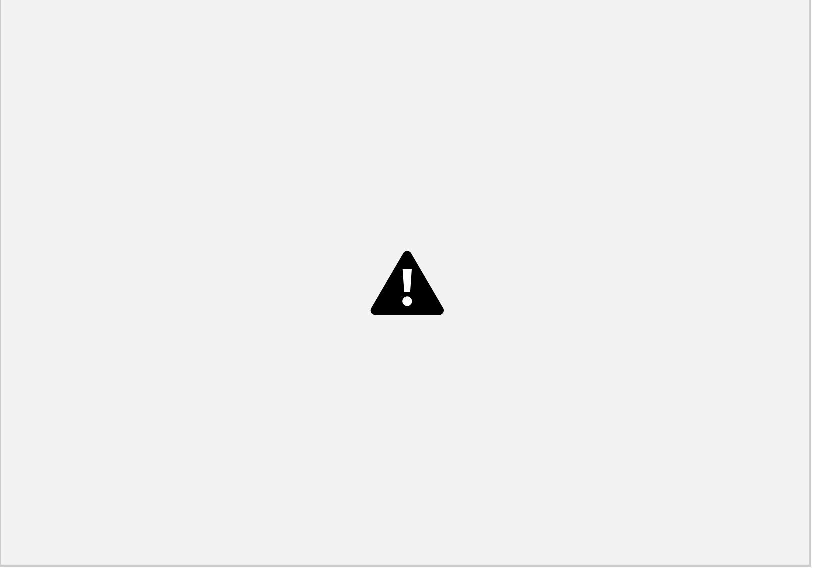
Dehydrated fruits and vegetables can be produced by a variety of processes. These processes differ primarily by the type of drying method used. The selection of the optimal method is determined by quality requirements, raw material characteristics, and economic factors.

There are three types of drying processes:

• Sun and solar drying,
• Atmospheric dehydration including stationary or batch processes (kiln,
Oven, and cabinet/tray dryers) and continuous processes (tunnel, continuous belt, fluidized-bed, foam mat, spray, drum and microwave heated dryers), and
• Sub-atmospheric dehydration (vacuum belt, vacuum drum and freeze dryers).

Sweating

Sweating is a practice of storage of dried product in bins or boxes for equalization of moisture or re-addition of moisture to a desired level. It is used primarily with some dried fruits and some nuts (almonds and walnuts).

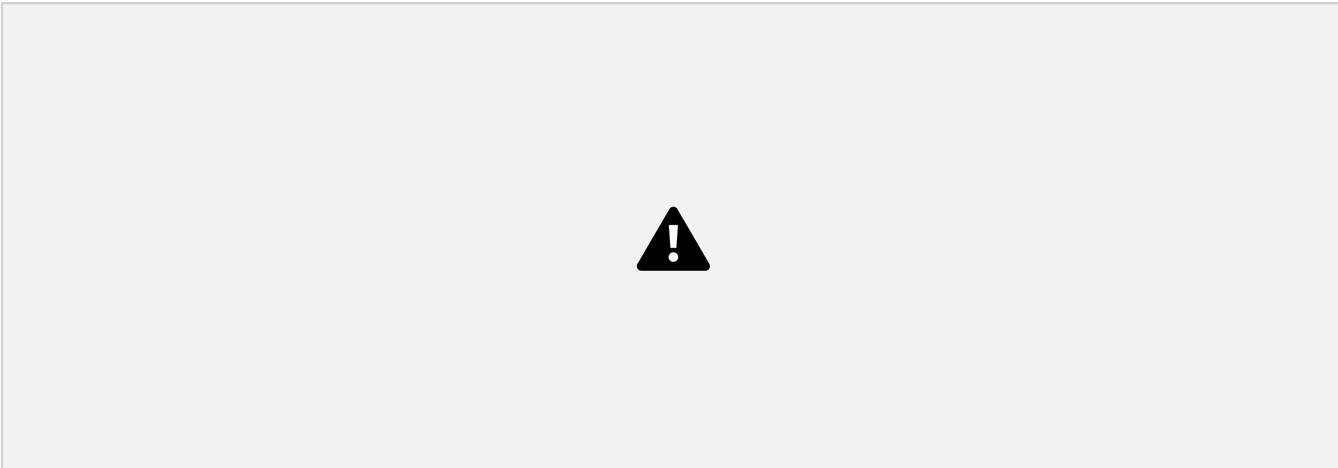


Packaging

Most product are packaged after drying for protection against moisture, contamination with micro-organisms, and infestation with insect, although some dried foods (e.g. fruits and nuts) may be held as long as a year before packaging.

RATE OF RYING

The rate at which drying occurs has been found to show certain phases. Consider the case where water is being removed from a solid under such conditions that the water is present as a liquid on the surface of the solid. If hot air is passes over the surface and act as heat source, the air and water will be in direct contact, and the resistance to heat and mass transfer will be due only to the liquid and gas films. If water is not present at the surface, evaporation will occur beneath the surface or on a reduced surface area. Thus rate of drying should be greatest at the beginning *when* water covers the entire surface of the solid. As drying proceeds, water is no longer available at the surface and rate of drying will decrease.If we plot moisture content against time OR rate of drying against moisture content:-



Drying Curve

Constant rate period (AB)-During the constant rate period, it is assumed that drying takes place from a saturated surface of the material by diffusion of the water vapor. Water can move freely from the interior of the slab to the surface to replace that lost by evaporation.

Falling rate period (BC)-The point B represent conditions where the surface is no longer capable of supplying sufficient free moisture to saturate the air, Rate of drying is decreases. In this case factor influencing the rate of drying is the mechanism by which the moisture from inside the material transferred to the surface.

Equilibrium moisture content (E.C.)-- At the end of falling rate period the moisture content referred to equilibrium moisture content

Critical moisture content (C. M. C.)-At the end of constant rate period, the moisture content referred to critical moisture content. Critical moisture content being low with non-porous materials (sand) while high with colloidal substances.

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ADVANTAGES OF DEHYDRATED FRUITS AND VEGETABLES

Fruits and vegetables that are properly dehydrated, particularly to a low moisture level (below 5%) have the following advantages:

Dehydration hardly affects the main calorie – providing constituents of fruit. It leaves the mineral content virtually unchanged.

The process is helpful in preserving the nutritive content of the final product.

Vitamin losses are no grater with dehydration than with other preservation methods.

Dried fruits and vegetables have an almost unchanged shelf-life under proper storage conditions and there is no greater degree of bacteria, enzymatic changes, and mould actions.

Transportation, handling and storage costs are substantially lowered, and need of costly refrigeration during transportation and storage is eliminated.

Due to their reduction in average weight of $1/7^{th}$ to $1/9^{th}$ of the raw material shipping and handling weight is therefore reduced by approximately 90%.

They provide consistent product, an important modern marketing requirement.

Seasonal variation in product quality is either absent or at a minimum with low –moisture fruits and vegetables.
They provide opportunities for maximum convenience, flexibility, and economics in production because they can be sized, shaped, formed, etc, to fit almost any requirement. With low moisture disposal and pollution problems.
They offer many distinctive conventional as snack products.

FACTORS AFFECTING DRYING
Food dehydration involves two steps
to get heat into the product
to get moisture out of the product.
Surface area
The heat and mass transfer is affected by surface area and higher surface area result into increased rate of drying. Therefore, the food to be dehydrated is sub divided into small pieces or thin layers which speeds drying for two reasons. First larger surface area provides more surfaces in contact with the heating medium and thus, more surface area from which moisture can escape. Second smaller particles or thinner layers reduce the distance through which heat must travel to the centre of the food and reduce the distance through which moisture in the centre of the food must travel to reach the surface and escape.
Air velocity
High velocity air, in addition to taking up moisture will sweep it away from the drying foods surface, preventing the moisture from making a saturated atmosphere which would slow down subsequent moisture removal.
Dryness of the air
When the food dried in air, then food will dried rapidly due to more absorption and more holding capacity of moisture by dry air than the moist air. Moist air is closer to saturation and so can absorb and hold less additional moisture, the extent of dryness of the air also determines how a low moisture content food product can be dried to low moisture content. Dehydrated food is hygroscopic and each food has own its equilibrium relative humidity. Equilibrium relative humidity (ERH) is the humidity at a given temperature where the food will neither lose moisture to the atmosphere nor pick upmoisture from the atmosphere.

The removal of moisture from a food product is one of the oldest preservation methods. By reducing the water content of a food product to very low levels, the opportunity for microbial deterioration is eliminated and the rates of other deteriorative reactions are reduced significantly.

A dryer (or drier) is a machine or apparatus used to remove moisture. It may be a small laboratory oven taking a few grams of moist material or a large industrial unit handling tones of wet feed per hour. However, there are three principal factors that define the nature of a dryer:
The method of material conveyance through the drying section;
The method of heating the material;
The pressure and temperature of operation.
The systems we will describe are representative of the systems used for dehydration of foods.

Classification of Dryers:

Classification of dryers on the basis of the mode of thermal energy input is the most useful to identify some key features of each class of dryers.

Direct dryers
This type of dryers is also known as convective dryers. In direct dryers, the drying medium contacts the material to be dried directly and supplies the heat required for drying by convection; the evaporated moisture is carried away by the same drying medium. Drying gas temperatures may range from 50º C to 400º C depending on the material.
Indirect dryers

This involve supplying of heat to the drying material without direct contact with the heat transfer medium, i.e., heat is transferred from the heat transfer medium (steam, hot gas, thermal fluids, etc.) to the wet solid by conduction. Vacuum operation also eases recovery of solvents by direct condensation thus alleviating serious environmental problem.

SELECTION OF DRYERS

Selection of the best type is a challenging task. A wrong dryer for a given application can give a loss not only to cost but also quality and quantity of product. Note that minor changes in composition or physical properties of a given product can influence its drying characteristics, handling properties. Following information is necessary to select a suitable dryer:
Dryer throughput; mode of feedstock production (batch/continuous)
Physical, chemical and biochemical properties of the wet feed as well as desired product specifications; expected variability in feed characteristics
Upstream and downstream processing operations
Moisture content of the feed and product
Quality parameters (physical, chemical, biochemical)
Safety aspects, e.g., fire hazard and explosion hazards, toxicity
Value of the product
Need for automatic control
Toxicological properties of the product
Turndown ratio, flexibility in capacity requirements
Type and cost of fuel, cost of electricity
Environmental regulations
Space in plant

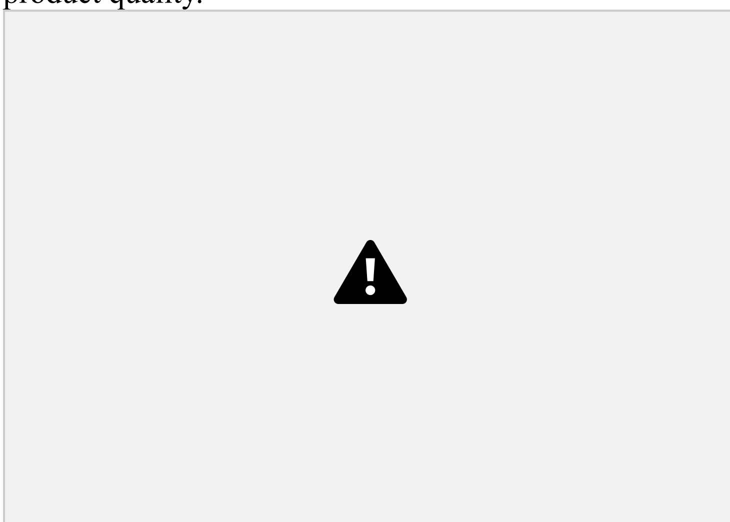
For high value products like pharmaceuticals, certain foods and advanced materials, the cost of dryer is not an important factor.

Drying of food and biotechnological products require GMP (Good Manufacturing Practice) and hygienic equipment design and operation. Such materials are subject to thermal as well as microbiological degradation during drying as well as in storage.

If the feed rate is low (< 100 kg/h), a batch-type dryer may be suited. Note that there is a limited choice of dryers that can operate in the batch mode.

Tray or Cabinet Dryers

These types of drying systems use trays or similar product holders to expose the product to heated air in an enclosed space. The trays holding the product inside a cabinet or similar enclosure are exposed to heated air so that dehydration will proceed. Air movement over the product surface is at relatively high velocities to ensure that heat and mass transfer will proceed in an efficient manner. A cabinet dryer can be operated under vacuum for heat-sensitive materials or when solvents must be recovered from the vapor. The reduction in pressure reduces the temperature at which product moisture evaporates, resulting in improvements in product quality.



A cabinet dryer of about 1000 sq ft of tray will handle from 1000 to 1500 pounds of fresh prepared vegetables every 6 or 7 hours.

In most cases, cabinet dryers are operated as batch systems and have the disadvantage of non-uniform drying of a product at different locations within the system. Improper loading of trays can also cause poor distribution of drying air and hence poor dryer performance. These dryers require large amount of labor to load and unload the product. Normally, the product trays must be rotated to improve uniformity of drying.

Applications

Tray dryers are used for diverse drying applications like food, electrodes, bakery, plastic & powders and drying of pigments.

Tray dryer is used in the industries where drying and heating are the essential parts of the manufacturing process.

Thermostatic inner chamber of the dryer is fabricated using mild steel and stainless steel and its temperature ranges from 50C to 150C.

Pneumatic/Flash Dryer

The pneumatic or 'flash' dryer is used with products that dry rapidly or where any required diffusion to the surface occurs readily. Drying takes place in a matter of seconds. Wet material is mixed with a stream of heated air (or other gas), which conveys it through a drying duct where high heat and mass transfer rates rapidly dry the product.

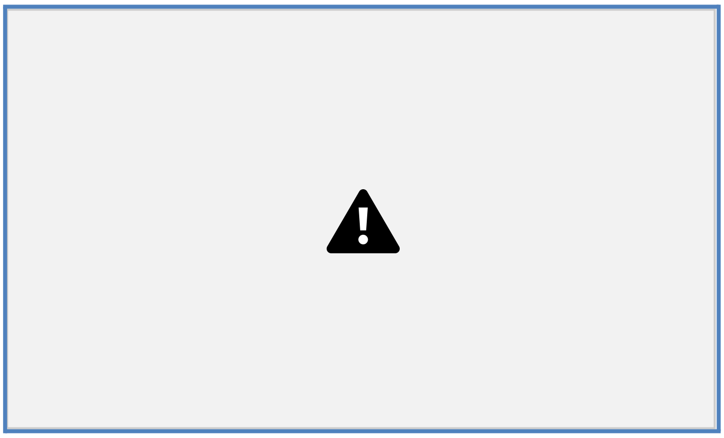
Applications include the drying of filter cakes, crystals, granules, pastes, sludge and slurries; in fact, almost any material where a powdered product is required. Salient features are as follows.

Particulate matter can be dispersed, entrained and pneumatically conveyed in air. If this air is hot, material is dried.

Pre-forming or mixing with dried material may be needed feed the moist material.

The dried product is separated in a cyclone. This is followed by separation in further cyclones, fabric sleeve filters or wet scrubbers.

This is suitable for rapidly drying heat sensitive materials. Sticky, greasy material or that which may cause attrition (dust generation) is not suitable.



Applications

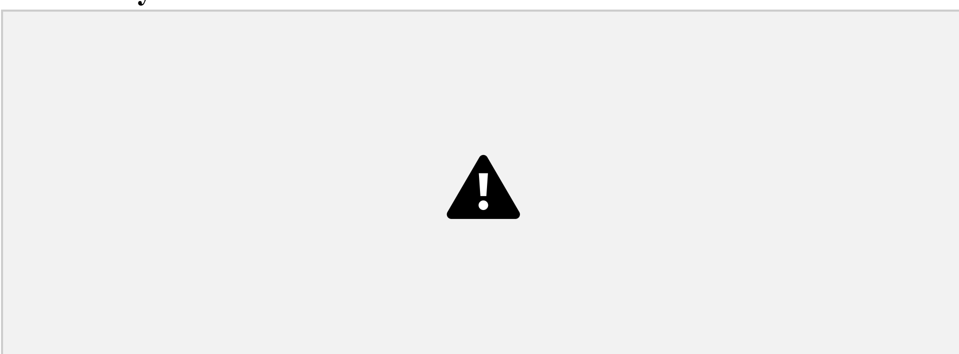
The main application is found in rubber additives, biological feed, PVC, fish meal, salt, feed, mineral powder, coal powder, polypropylene, sodium sulfate, benzoic acid, gluten, plastic resins, potato powder, corn gluten powder, medicines, alcohol dregs.

the mineral industry, potassium, lead or magnesium derivates,

the food industry: starch, casein,

the organic products: filter, cakes.

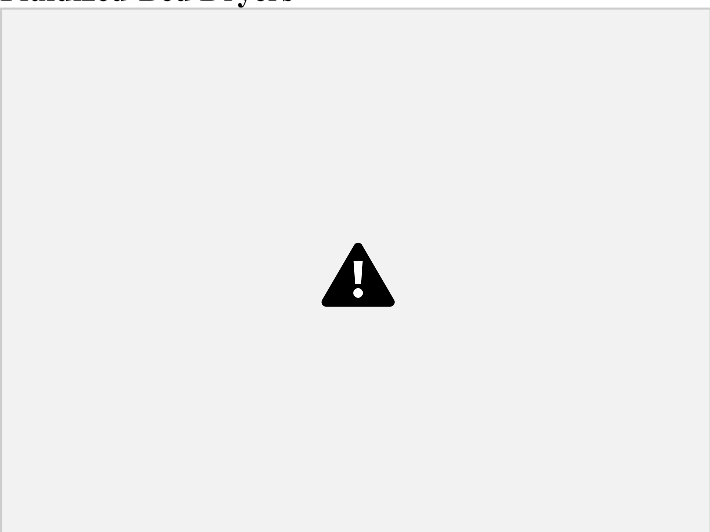
Tunnel Dryers



In tunnel dryers the heated drying air is introduced at one end of the tunnel and moves at an established velocity through trays of products being carried on trucks. The product trucks are moved through the tunnel at a rate required to maintain the residence time needed for dehydration. The product can be moved in the same direction as the air flow to provide concurrent dehydration, or the tunnel can be operated in countercurrent manner, with the product moving in the direction opposite to air flow.

The arrangement used will depend on the product and the sensitivity of quality characteristics to temperature. The overall efficiency of the countercurrent system may be higher than the concurrent; product quality considerations may not allow its use.

Fluidized-Bed Dryers



A second relatively new design for drying solid-particle foods incorporates the concept of the fluidized bed. In this system, the product pieces are suspended in the heated air throughout the time required for drying. The movement of product through the system is enhanced by the change in mass of individual particles as moisture is evaporated. The movement of the product created by fluidized particles results in equal drying from all product surfaces. The primary limitation to the fluidized-bed process is the size of particles that will allow efficient drying. As would be expected, smaller particles can be maintained in suspension with lower air velocities and will dry more rapidly. Although these are desirable characteristics, not all products can be adapted to the process.

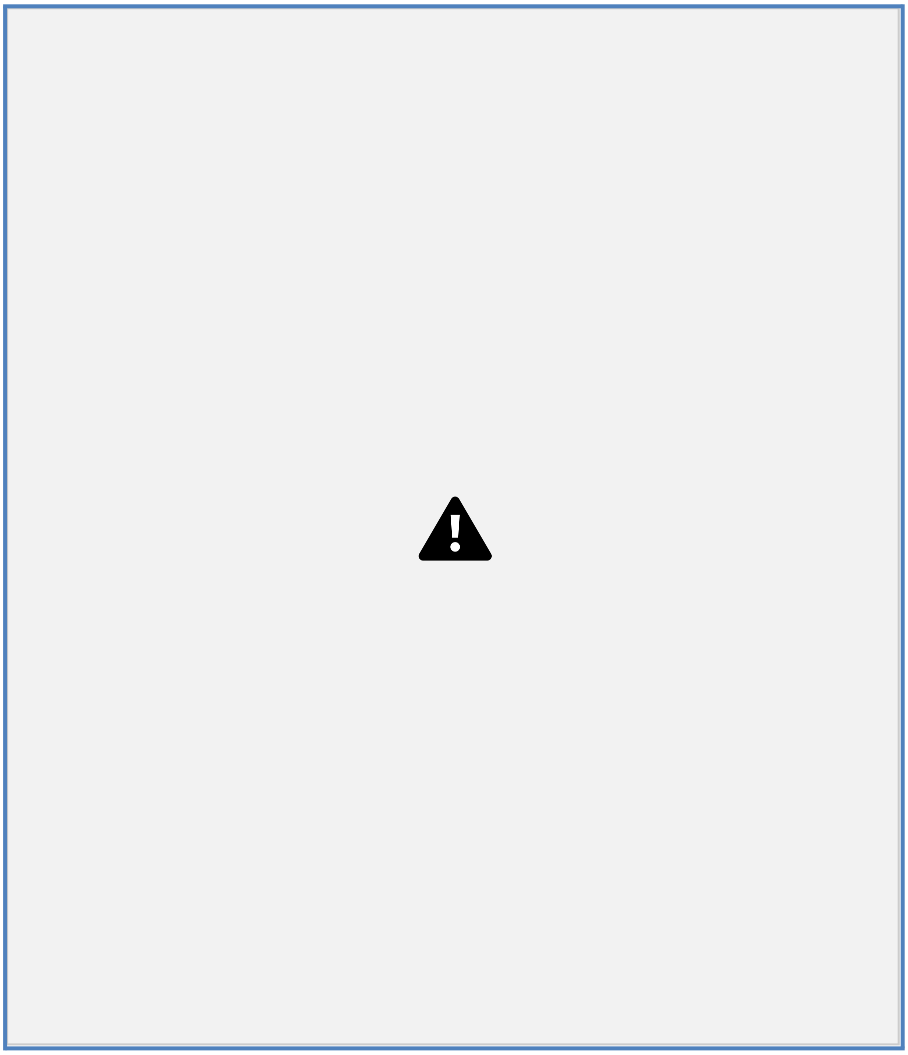
Applications

Food industry: Cereals, Coffee, Grains, Animal food, Rice, Tea....

Minerals & Mining: Coal, Coke, Copper Sulphate, Limestone.......
Pharmaciuticals: Lithium carbonate, Salicylic Acid, Pancreatic Bile acid and salts.......
Chemical & Biochemical: General chemicals, Drying Agents, Ion exchange Resins.....

Spray Dryer

Spray drying has been one of the most energy-consuming drying processes, yet it remains one that is essential to the production of dairy and food product powders. Basically, spray drying is accomplished by atomizing feed liquid into a drying chamber, where the small droplets are subjected to a stream of hot air and converted to powder particles. As the powder is discharged from the drying chamber, it is passed through a powder/air separator and collected for packaging. The dried product is then placed in a sealed container at moisture contents that are usually below 5%. Product quality is considered excellent due to the protection of product solids by evaporative cooling in the spray dryer. The small particle size of dried solids promotes easy reconstitution when mixed with water. Most spray dryers are equipped for primary powder collection at efficiency of about 99.5%, and most can be supplied with secondary collection equipment if necessary

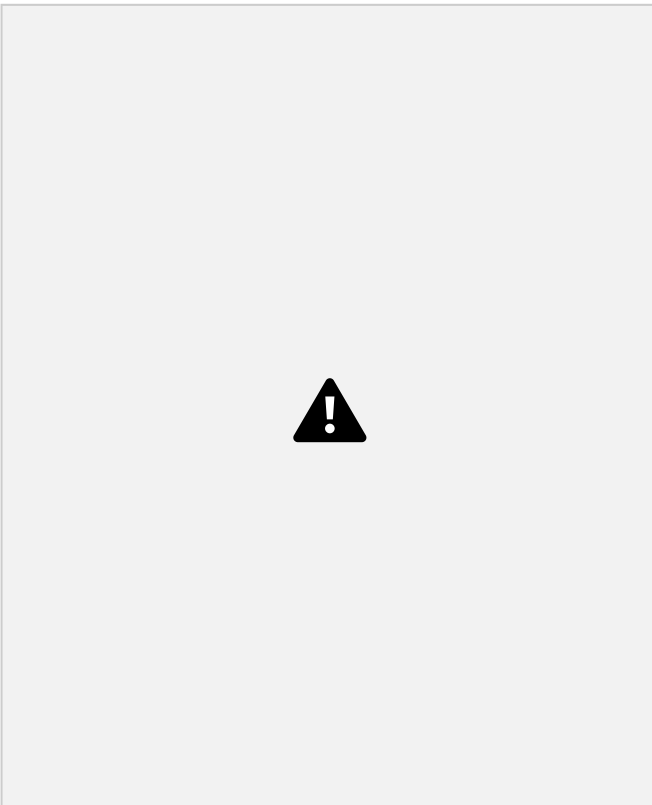


Applications

Food: milk powder, coffee, tea, eggs, cereal, spices, flavorings, starch and starch derivatives, vitamins, enzymes, colorings...

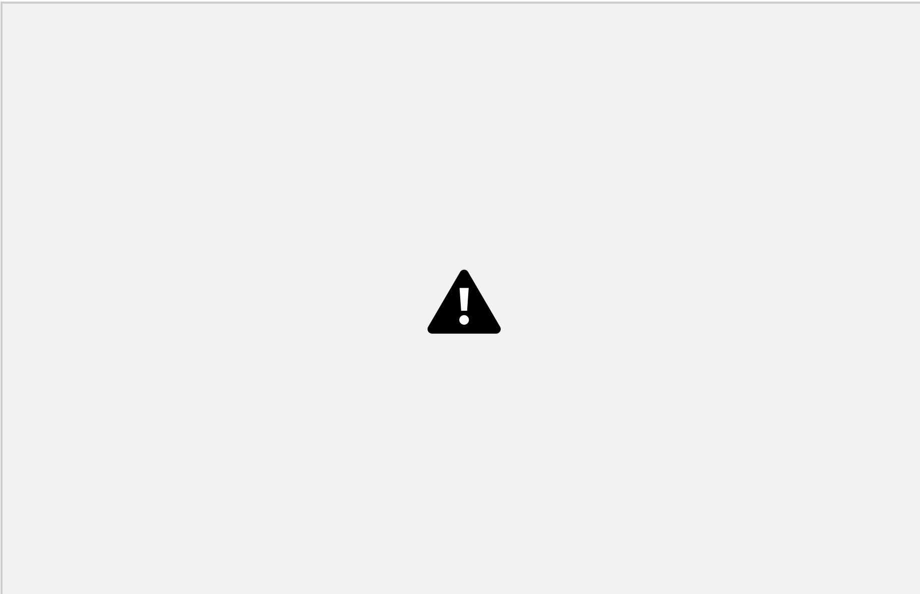
Pharmaceutical: antibiotics, medical ingredients, additives

Industrial: paint pigments, ceramic materials....



Freeze-Dryer

Freeze-drying, also known as **lyophilization,** is a dehydration process typically used to preserve a perishable material or make the material more convenient for transport. Freeze-drying works by freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublimate directly from the solid phase to the gas phase. Because of the low temperature, low pressure, and low drying rate, freeze drying is quite expensive compared to many other drying methods. But freeze drying can produce high quality dried products. Thus, it is the preferred drying method for some high value materials.



If a freeze-dried substance is sealed to prevent the reabsorption of moisture, the substance may be stored at room temperature without refrigeration, and be protected against spoilage for many years.

Freeze-drying also causes less damage to the substance than other dehydration methods using higher temperatures. Freeze-drying does not usually cause shrinkage or toughening of the material being dried. In addition, flavours, smells and nutritional content generally remain unchanged, making the process popular for preserving food.

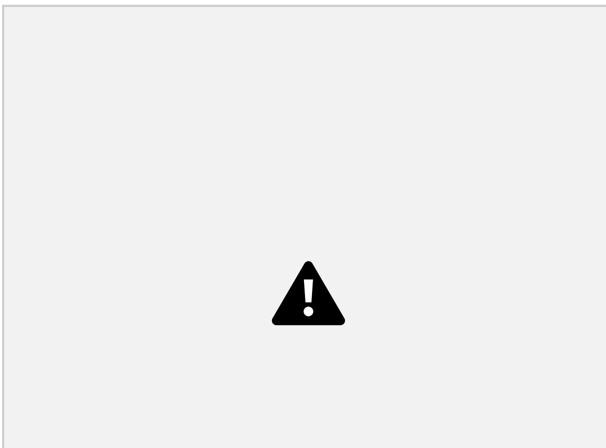
Freeze-dried products can be rehydrated (reconstituted) much more quickly and easily because the process leaves microscopic pores. Freeze-drying can also be used to increase the shelf life of some pharmaceuticals for many years.

Applications

Pharmaceutical companies often use freeze-drying to increase the shelf life of the products, such as vaccines.
In pharmaceutical industry freeze drying to produce tablets or wafers,
Instant coffee is sometimes freeze-dried, despite the high costs of the freeze-driers used.
Freeze-dried fruits are used in some breakfast cereal or sold as a snack,
From early 1970s freeze-drying is used in agriculturally based industries was in processing of crops such as peanuts/groundnuts and tobacco.

Drum-Dryers

These may be atmospheric or vacuum, consisting of stem heated drums 2 to 6 feet in diameter to which to be dried is applied by feeding device. The drums may be single or double. The drums revolve and before they have to make one complete their revolution, the material is sufficiently dry to be removed by “Doctor Blade” or scraper. The wet material is fed onto the drums by any one of several arrangements: by spray feeding system or by perforated pipe. The feed method is depending upon the type of material being dried.



Applications

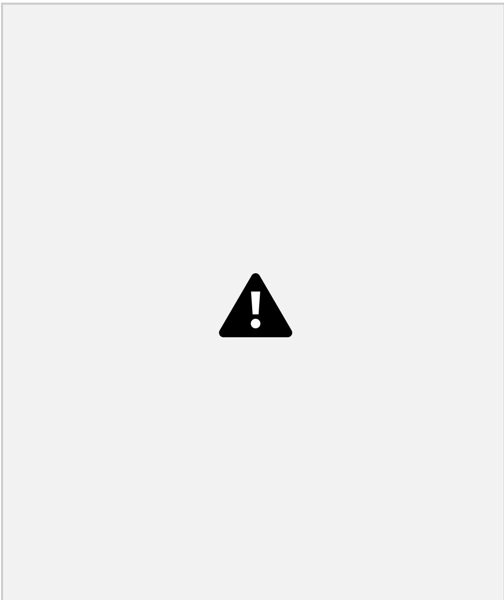
Drum dryers are mainly used to convert molten chemicals into solid flakes. Solidified material is thus flaked by an adjustable scraper.

The dryer drum is accurately fabricated to ensure proper heating of aggregates with minimum heat loss.

Rotary dryers are used for drying high viscosity liquids or pasty materials such as potato starches, gelatins, adhesives and synthetic resins.

Kiln Dryers

These type dryers are sometimes called “evaporators” and are used chiefly for drying apples and hops. A kiln consists of a two-story arrangement, the lower floor or cellar being provided with a stove or furnace and fume pipe. The heating pipes of the furnaces are arranged so that the warm air is equally distributed underneath the ceiling of the cellar. The ceiling consists of narrow slots and the air passes between the slats into the first floor. The material to be dried is spread evenly to a depth of 4 to 8 inches on the slatted floor. To facilitate air movement, intake ducts are cut into the lower parts of the cellar walls, and on the first floor. The air is passed outside. Air movement, with this arrangement, depends upon the convection and of course passage of the hot air through the material cannot be controlled.



Some kilns are therefore provided with fans. Potato requires 12 to 14 hours to dry in kiln and it is necessary to turn the material several times during operation.

Vacuum Dryer

In vacuum drying, the product is placed inside a chamber where the pressure is reduced to produce a vacuum. Since the total pressure of chamber and the partial pressure of the water vapor in the chamber is also very low. This low partial pressure causes a large partial pressure difference between the water in the product and the surroundings. Thus, water moves more readily from the product to the surrounding environment in the chamber. Drying under vacuum conditions permits drying at a lower temperature. This characteristic of vacuum drying is very important for products that may suffer significant flavor changes at higher temperatures. One advantage to vacuum drying is that it conserves energy. Less energy is needed for drying, cutting down economic and environmental costs. This process works faster than other drying methods and cutting down processing time.

Evaporation, concentration, drying and dehydration, types of dryers, advantages and disadvantages, selection of dryers.

EVAPORATION PROCESS: -

Evaporation is a heating process in which water is removed from the liquid substance. The simplest kind of evaporation process is, water evaporates from the sea and leaves salt behind. Other example of evaporation occurs when we boil sugar and water solution continuously, the syrup converted into a hard sugar ball. This is because of evaporation of water. The goal of evaporation is to vaporize most of the water from a solution which contains the desired product. Evaporation is one of the most important unit operations in food processing. Large quantities of fruit and vegetable juices, sugar, and syrups are concentrated in several types of commercial evaporators. In the food industry a raw material contains more water than is required in the final product. When the foodstuff is a liquid, the easiest method of removing the water, in general, is to apply heat to evaporate it. Evaporation is thus a process that is often used by the food technologist.

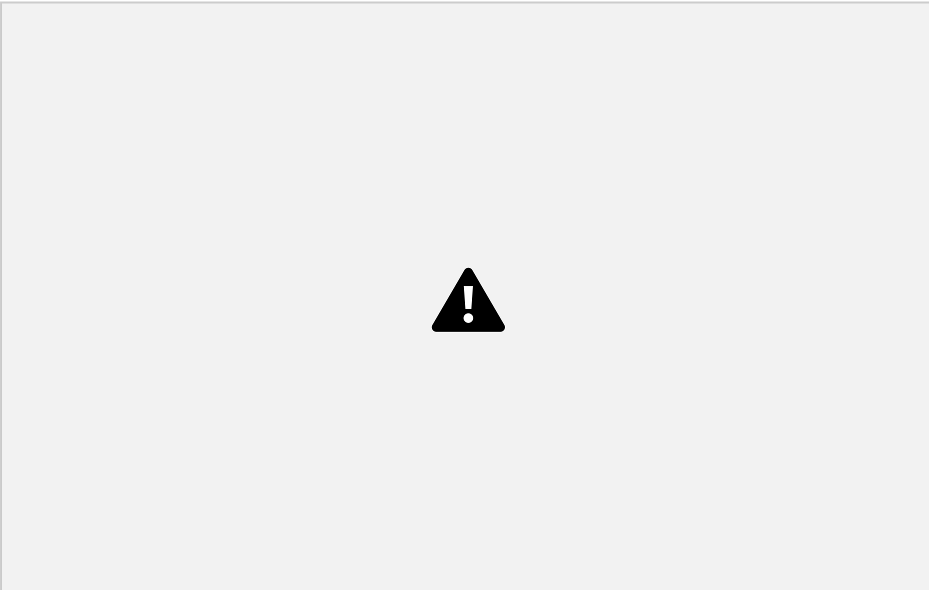
Typical process applications:

Food and dairy products,
Whey or milk proteins,
Fruit and vegetables juices,
Various extracts,
Fine chemicals evaporation.
Distillery industries
Brine concentration
Textile industry
Coffee extracts

Pharmaceutical products.

Evaporators: -

An evaporator is a device used to turn the liquid form of a chemical into its gaseous form. The liquid is evaporated, or vaporized, into a gas. Many types of evaporators and many variations in processing techniques have been developed to take into account different product characteristics and operating parameters.



Single effect evaporator

TYPES OF EVAPORATORS: The more common types of evaporators include:-

Batch pan Evaporators

Forced Circulation Evaporators

Rising film Evaporators

Falling film Evaporators

Rising/Falling film Evaporators

Batch pan evaporator: - The batch pan evaporator **is** one of the simplest and oldest types of evaporators used in food industry. Now-a-days it is outdated technology, but it still used in a few limited applications, such as the concentration of jams and jellies where whole fruit is present and in processing some pharmaceutical products.

Natural Circulation: - In Natural Circulation evaporators, short vertical tubes, typically 1-2 m long and 50-100 mm in diameter, are arranged inside the tubes, and the product is concentrated.

Rising-film Evaporators: -These are considered to be the first 'modern' evaporator used in the industry. The rising film principle was developed commercially by using a vertical tube heated from the outside with steam. Liquid on the inside of the tube is brought to a boil, with the vapor generated forming a core in the center of the tube. As the fluid moves up the tube, more vapors are formed resulting in a higher central core velocity those forces the remaining liquid to the tube wall.

Falling film Evaporator: -The falling-film evaporators have a thin liquid film moving downward under gravity on the inside of the vertical tubes. The design of such evaporators is complicated by the fact that distribution of liquid in a uniform film flowing downward in a tube is more difficult to obtain than an upward-flow system such as in a rising- film evaporator. This is accomplished by the use of specially designed distribution or spray nozzles. The falling-film evaporators allow a greater number of effects then the rising-film evaporator. The falling-film evaporator can handle more viscous liquids than the rising film type. This type of evaporators is best suited for highly heat sensitive products such as orange juice.

Rising/falling-filling Evaporator: - In the rising/falling evaporator, the product is concentrated by circulation through a rising-film section followed by a falling-film section of the evaporator. The product is first concentrated as it ascends through a rising tube section, followed by pre-concentrated product descending through a falling-film section; there it attains its final concentration.

Concentration

There may be some or many reasons of concentration of food. The concentration of food is based upon the fact that many foods contain a large percentage of free water. Concentration is the process which is used not preserve the food and o\in some cases it facilitates next step of processing. Like In dehydration the early stages of water removal, moisture can be more economically removed in highly efficient evaporators than in dehydration equipment. Concentration can be a form of preservation but this is true only for some foods. Nearly all liquid foods which are dehydrated are concentrated before they are dried because

Some concentrated foods are desirable components of diet in their own right. For example, concentration of fruit juices plus sugar yields jelly.
Many concentrated foods, such as frozen orange juice concentrate and canned soups , are easily recognized because of need to add water before they are consumed.

Benefits:

Concentration reduces weight and volume and results in immediate economic advantages.
It is prior to concentrate the liquid food before dehydration because in the early stages of water removal, moisture can be more economically removed in highly efficient evaporators than in dehydration equipment.
Increased viscosity from concentration often is needed to prevent liquids from running off drying surfaces or to facilitate foaming or puffing.
Concentrated forms have become desirable components of diet in their own right.

Methods of concentration

Solar concentration

Uses solar energy
Used to derive salt from seawater in earlier times
Being practiced today in united states in manmade lagoons
Slow process and suitable only for concentrating salt solutions

Open Cattles

Heated by steam
Being used for some jellies and jams for certain types of soups
High temperatures and long concentration times causes damage to food
Thickening and burn on of product to cattle wall gradually lower the efficiency of heat transfer and slow concentration process
Widely used in manufacture of maple syrup

Flash Evaporators

Subdivides food material and brings it into direct contact with the heating medium to speed up concentration process.
Superheated steam at 150°C is used

Some other Methods Changes

Thin film evaporators
Vacuum evaporators
Freeze concentration
Ultra filtration and reverse osmosis

Changes during concentration

Concentration processes that expose food to 100°C or higher temperatures for prolonged period can cause major changes in organoleptic and nutritional properties. Also these changes are different for different food products. Two more common changes are
Cooked flavors and

Darkening of color

Some other changes

Heat induced reactions

In case of sugar, crystallization of sugar that can result in gritty, sugar jellies or jams.

Crystallization of lactose due to overconcentration 'sandiness', in case of certain milks.

Proteins can be easily denatured and precipitated from solution due to high concentration of salts and minerals in solution with protein.

Proteins can be easily denatured and precipitated fro solution due to high concentration of salts and minerals in solution with protein.

The gelation of concentrated milk and other proteinacious foods.

Microbial destruction, largely dependent on temperature

Preservation by Low Temperature- Low temperature required for different foods – refrigeration – refrigeration load, refrigeration systems; slow and fast freezing, freezing process; types of freezer advantages and disadvantages of freezing; storage and thawing of frozen food.

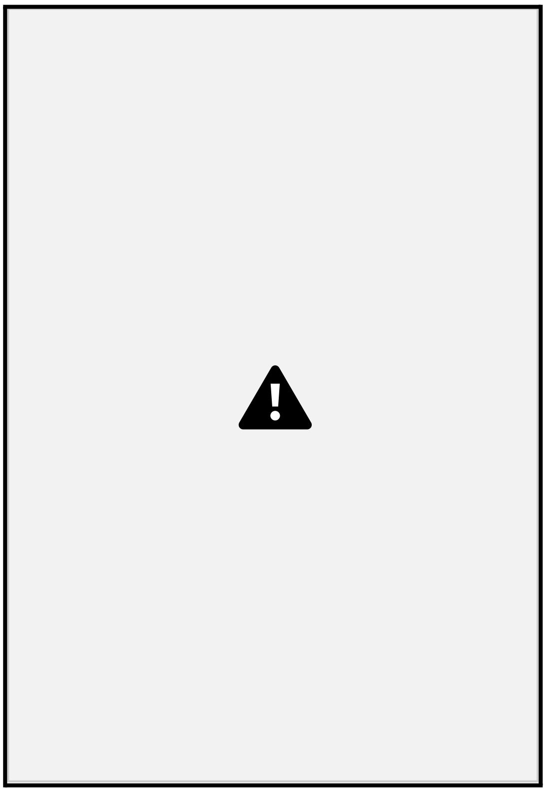
Food preservation

The term **food preservation** refers to any one of a number of techniques used to prevent **food** from spoiling. It includes methods such as canning, pickling, drying and freeze-drying, irradiation, pasteurization, smoking, and the addition of chemical additives.

Food preservation involves preventing the growth of bacteria, fungi (such as yeasts), or other microorganisms (although some methods work by introducing benign bacteria or fungi to the food), as well as retarding the oxidation of fats that cause rancidity. Food preservation may also include processes that inhibit visual deterioration, such as the enzymatic browning reaction in apples after they are cut during food preparation.

History of food preservation

In 1876 the 'father of refrigerating engineering' Charles Tellier for the first time in history organized intercontinental sea transport of chilled meat from Europe to South America (12000 km) and back. The ship's name was 'Le Frigorifique'. It is also worth noting that in 1978 we celebrated the hundredth anniversary of the opening of the first machine-cooled cold store in Chicago. Those events revolutionized the world food economy and provided the basis for the development of a modern 'refrigeration chain'. Cryogenic engineering started to develop at the turn of the 19th century, when Olszewski and Wróblewski, and Carl von Linde carried out liquefaction of gas.



The freezing process consists of pre-freezing operations, freezing, and frozen storage. Depending on the food being frozen, some pre-freezing steps are: washing, husking, shelling, cutting, boning, trimming, pitting, and slicing. Inspection and grading on long moving belts, formerly a visual operation, is now being increasingly mechanized.

Fruits may have sugar or syrup added, and vegetables may be subjected to steam or hot water blanching to retard enzymatic or chemical changes such as browning and off-flavor development that can occur during subsequent storage. Filling and sealing of packages are usually done by complicated machines designed for the purpose.

FREEZING TECHNOLOGY

Basically, there are three methods of preservation. Their main aim is to control the activities of microorganisms. In short you can also refer to them as 3K's.They are
1) Keep them away
2) Kill them
3) Keep them away from growing

The Freezing technology is based on the third principle of preservation which is **Keep them away from growing**. Temperature of the product to –10°C to –20°C Low temperature retards the biochemical reactions occurring in foods and prevents biochemical reactions in food. Microorganisms also get inactivated at low temperature. But the formation of ice crystals within the structure of most food products creates changes in the structure and gives negative changes in the quality characteristics of the product.

Freeze food required continuous maintaining the low temperature not only during process but also during storage and distribution.

Freezing

Freezing is the removal of heat from the packaged or whole foods resulting in the temperatures between slightly below the freezing point of food to -18°C. Frozen foods last many months without spoiling however, some quality loss may occur.

Some microorganisms grow even at sub-freezing temperatures as long as water is available. Conversion of water to ice increases the concentration of dissolved solutes in unfrozen water and leads to low water activity. Freezing prevents the growth of microorganisms due to reduced water activity. The concerted effect of low temperatures, reduced water activity, and pre-treatment of blanching prior to freezing of products yield longer shelf life.

Different types of freezing systems are available for foods. No single freezing system can satisfy all freezing needs, because of the wide variety of food products and process characteristics. The selection criteria of a freezing system will depend on the type of the product, reliable and economic operation, easy cleanability, hygienic design and desired product quality.

Although all commercial freezing processes are operated at atmospheric conditions, there are potential applications of high-pressure assisted freezing and thawing of foods. The pressure–induced freezing point and melting point depression enables the sample to be super cooled to low temperature (e.g. -22°C at 207.5 M pa) resulting in rapid and uniform nucleation and growth of ice crystals on release of pressure.

Freezing systems based on time taken for freezing
Freezing systems based on time required to freeze foods can be classified into two types i.e. slow and quick freezing. Rate of freezing affects the quality of frozen food.

Slow freezing:
Slow freezing occurs when food is directly placed in freezing rooms called sharp freezers. It is also known as sharp freezing. This method involves freezing by circulation of air by convection i.e. through a specially insulated tunnel, either naturally or with aid of fans. The relatively still air is a poor conductor of heat and that is the reason for long time required to freeze the food.
The temperature ranges from -15 to -29°C and freezing may take from 3 to 72 hours. The ice crystals formed are large and found in between cells i.e. extra-cellular spaces because of which the structure of food is disrupted.
The structure of food is not maintained and thawed food cannot regain its original water content. Large ice crystals create quality problems like mushiness in vegetables etc.

Quick freezing:
Vigorous circulation of cold air enables freezing to proceed at a moderately rapid rate. In this process, the temperature is kept between -32°C to -40°C and the food attains the stage of maximum ice crystal formation in 30 minutes or less.
Small ice crystals are formed within the cells and therefore, it does not damage the structure of food. On thawing, the structure of original food is maintained.

Difference between sharp and quick freezing

Sharp freezing	**Quick freezing**

• Rates of cooling of less than 1°C/min. Ice crystals form in extra-cellular locations • Large ice crystals formation • Maximum dislocation of water • Shrinkage (shrunk appearance of cells in frozen state) • Less than maximum attainable food quality	• Produces both extra-cellular and intracellular (mostly) locations of ice crystals • Small but numerous ice crystals • Minimum dislocation of ice crystals • Frozen appearance similar to the unfrozen state • Food quality usually superior to that attained by slow freezing

The advantages of quick freezing over slow freezing are that:

- smaller ice crystal is formed hence there is less mechanical destruction of intact cells of the food;
- there is shorter period of solidification and therefore less time for diffusion of soluble materials and for separation of ice;
- there is more prompt prevention of microbial growth;
- there is more rapid slowing down of enzyme action.
- Quick frozen foods therefore are supposed to thaw to a condition more like that of the original food than slow-frozen foods

THE FREEZING POINT OF FOODS

Living cells contain much water, often two-thirds of more of their weight. In this medium there are organic and inorganic substances, including salts and sugars and acids in aqueous solutions, and more complex organic molecules, such as proteins which are colloidal suspension. Thus more the salt, sugar, minerals and proteins in a solution the lower its freezing point (depression of freezing point) and the longer it will take to freeze when put in freezing chamber. If water and fruit juice for example are placed in a freezer, the water will freeze first.

The freezing time depends upon number of factors such as dimensions, shape of product, thermal properties, and temperature of refrigerant medium.

Frozen foods have great advantage is microorganisms do not grow in foods when the temperature is –10°C or colder. Generally freezing preserves taste, texture and nutritional value of foods better than any other preservation method.

The common terms are Cool Storage, Refrigeration and Freezing. Let us see what the difference between each other is

Difference between cool storage, refrigeration and freezing

	Temperature	
Cool storage	16 to –2°C	Microorganism Spoilage microorganism can grow rapidly at temp.>10°C. Some grow below 0°C if water is unfrozen.
Refrigeration	4.5-7°C	Pathogenic microorganisms grow slowly. Psychotropic Microorganisms grew
Freezing	-2°C to lower	No significant growth of spoilage or pathogenic m/o. However, multiplication of microorganisms can take place if food is thawed.
Freezer storage	–18°C	-----do---

WHY DO WE SEE MORE NEW REFRIGERATED FOODS ENTERING THE MARKETPLACE THAN OTHER FOODS?

1. Consumer demand for high quality foods:
1. Typically, less change in the quality of food product.
2. Convenient – shorter cook times
3. Changes in food distribution
4. Buying habits
5. Improved food distribution
6. Improved processing techniques
7. Aseptic processes
8. Gas storage [CA (controlled atmosphere and MAP (modified atmosphere packaging)]

Principles of Freezing

- Does not sterilize food.
- Extreme cold (0ºF or -18ºC colder):
  - Stops growth of microorganisms and
  - Slows chemical changes, such as. enzymatic reactions
- Freezing is the unit operation in which the temperature of a food is reduced below its freezing point and a proportion of the water undergoes a change in state to form ice crystals. The immobilization of water to ice and the resulting concentration of dissolved solutes in unfrozen water lower the water activity (a_w) of the food
- Preservation is achieved by a combination of *low temperatures*, *reduced water activity* and., in some foods, pre-treatment by blanching

Advantages of Freezing

- Many foods can be frozen.
- Natural color, flavor, and nutritive value retained.
- Texture usually better than other methods of food preservation.
- Foods can be frozen in less time than they can be dried or canned.
- Simple procedures. Adds convenience to food preparation.
- Proportions can be adapted to needs unlike other home preservation methods. Kitchen remains cool and comfortable
- Frozen food can be kept for a very long period of time. Usually about 3 months.

Deep freezing is the reduction of temperature in a food to a point where microbial activity cease

Disadvantages of Freezing

- Texture of some foods is undesirable because of freezing process.
- Initial investment and cost of maintaining freezer is high.
- Storage space limited by capacity of freezer

Methods of freezing

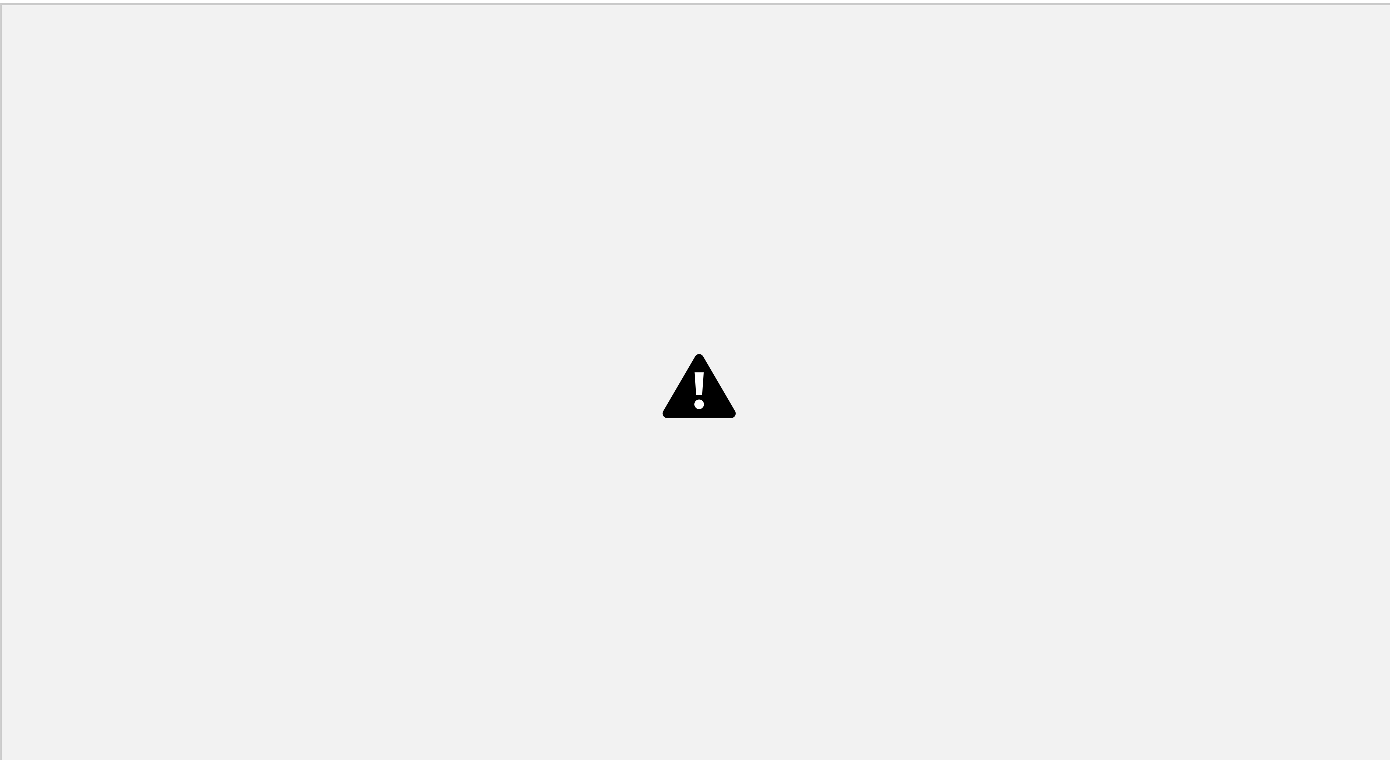
Freezing techniques include:

- The use of cold air blasts or other low temperature gases coming in contact with the food, e.g. blasts, tunnel, fluidized bed, spiral, belt freezers.

- Indirect contact freezing, e.g. plate freezers, where packaged foods or liquids are brought into contact with metal surfaces (plate, cylinders) cooled by circulating refrigerant (multi-plate freezers).
- Direct immersion of the food into a liquid refrigerant, or spraying liquid refrigerant over the food (e.g. liquid nitrogen, and freon, sugar or salt solutions).

Freezing Process of Water

The material to be frozen first cools down to the temperature at which nucleation starts. Before ice can form, a nucleus, or a seed, is required upon which the crystal can grow; the process of producing this seed is defined as nucleation. Once the first crystal appears in the solution, a phase change occurs from liquid to solid with further crystal growth. Therefore, nucleation serves as the initial process of freezing, and can be considered as the critical step that results in a complete phase change. During freezing of water, the water molecules arrange themselves in a tetrahedral fashion. These results in a hexagonal crystal lattice which is loosely built and has relatively large hallow spaces resulting in high specific volume. This is the reason for increase in volume of water on freezing. You must have observed ice cubes floating on water. The density of ice at 0° C is only 0.9168. Water can exist in three phases, viz., solid, liquid and gas.



Freezing

At temperature below the freezing point of water (-18 to -40^{0}C), growth of microorganisms and enzyme activity are reduced to minimum. Most perishable foods can be preserved for several months if the temperature is brought down quickly and the food is kept at these temperatures. Foods can be quickly frozen in about 90 minutes or less.

Quick frozen foods maintain their quality and freshness when they are thawed because only very small ice crystals are formed when foods are frozen in this manner. Frozen foods should, always be kept at temperatures, below -5^{0}C. Properly frozen (–12 to –17 ^{0}C by excluding air), juice retains its freshness, colour and aroma for a long time.

Refrigeration Load: -

A product refrigeration laud is the quantity of heat that must be removed to reduce the temperature of the product from its initial; temperature to the temperature consistent with good frozen food storage. Cooling load on the cooling system determines the size of the refrigeration, and, consequently, its energy consumption. (This does not affect the COP or efficiency: without cooling load will not be a COP or effectiveness.)

- Less load, the lower the power consumption.

Load, as a rule, consists of many different components. You may be able to reduce or eliminate one or more of them. Application storage (e.g. cold store or retail Cabinet) load includes:

- transmission load, which is heat transferred into the refrigerated space through its surface;
- product load, which is heat removed from and produced by products brought into and kept in the refrigerated space;
- internal load, which is heat produced by internal sources (e.g., lights, electric motors, and people working in the space);
- infiltration air load, which is heat gain associated with air entering the refrigerated space;
- equipment-related load.

Osmosis is the movement of water from **less concentrated** to the **more concentrated** solution through a semi-permeable membrane.
When we soak resins in water they swell up and this is all that happens due to osmosis. Water travels from high concentration to low concentration and keeps moving by osmosis until the equilibriumis reached, that is when the concentration of both solutions is the same INCLUDEPICTURE "https://studiousguy.com/wp-content/uploads/2019/03/soaked-and-dry-raisins.jpeg" * MERGEFORMATINET

Refrigeration Load

When computing refrigeration load, the most conservative approach is to calculate each part at its expected peak value. The combined result can overstate the actual total load by as much as 20 to 50%. Perhaps the heat loads of goods which are at a higher temperature than the temperature of storage. You pay for some of these heat gains in two times. For example, you pay for engine start evaporator fan, but you also pay for the cooling system to heat it puts at cooled space. Processing of applications, the majority of the heat loads, as a rule, from the product, chilled or frozen, although there may be stranger heat gains. More information about reducing these heat loads are given in the GPG 279 Cut employment costs for refrigeration.

Freezing Systems

The freezing process can be accomplished using either indirect or direct contact systems. Most often, the type of system used will depend on the product characteristics, before and after freezing is completed.

Freezing Systems Based on Mode of Operation

They are constructed for batch, continuous and batch/continuous modes of operation.

Batch freezing

This type of freezing is mostly used for small operations. If a variety of products are to be frozen, a batch freezer may be selected over continuous as they are more versatile. Such freezing systems are also likely to be used for products with longer freezing times since with a batch freezer there is better utilization of floor space due to the multi-layer arrangement of loading. It is difficult to choose on an exact line of demarcation but generally freezing times longer than one hour would usually require a batch mode of operation.

Continuous freezing

This process of freezing is used in large-scale production lines. Continuous freezers are best used for freezing individual portions, such as small pieces of vegetables. The main advantage in using a continuous freezer for these smaller and/or thinner products is that since they freeze quickly, they will also thaw quickly and the delays that occur with a batch-freezing operation may be overcome. Continuous freezing allows quick handling after freezing and a quick transfer to the cold store.

Batch/ continuous freezing

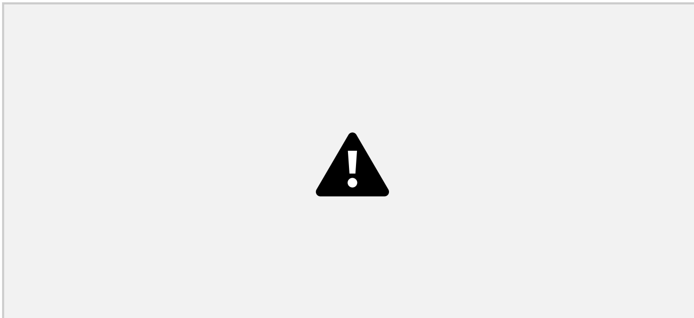
These kinds of freezers are usually batch type freezers operated with trolleys which are loaded in sequence at fixed-time intervals rather than all at one time as in the truly batch freezer.

Freezing systems Based on contact with the product

Based on the contact between food and the freezing medium, the freezing systems can be categorized in two categories viz. direct and indirect contact freezing .

Indirect Contact Systems

In numerous food products freezing systems the product and the refrigerant are separated by a barrier throughout the freezing process. This is called an indirect contact system. Although many systems use a non- permeable barrier between product and refrigerant, indirect freezing systems include any system without direct contact, including those where the package material becomes the barrier. These include plate freezer, air blast freezer and freezer for liquid foods.



Direct Contact Systems

Direct contact freezing systems operate with direct contact between the refrigerant and the product. In most situations these systems operate more efficiently since there is no barrier to heat transfer between the refrigerant and the product. All direct contact freezing systems are designed to achieve rapid freezing, and the term **individual quick freezing** (IQF) applies. IQF generally refers to freezing of solid food/pieces/grains like green peas, cut beans, cauliflower pieces, meat, fish etc. While quick freezing relates mostly to liquid, pulpy or semi liquid products like fruit juices, mango/papaya concentrates and purees etc. There is no clumping together of pieces or grains.

They remain individual separate pieces. Individual quick freezing has advantages:

• Smaller ice crystals are formed; hence, there is less mechanical destruction of intact cells of the food.

• More rapid prevention of microbial growth.

• More rapid slowing down of enzymatic action.

Disadvantages

Brine is a good refrigerating medium but it cannot be used for fruits.

It is very difficult to maintain the medium at a definite concentration and also to keep it free from dirt and contamination.

This includes fluidized bed freezing, immersion freezing and cryogenic freezing.

Direct Contact Systems Freezers: -

Fluidized-Bed Freezer

When the air velocity is increased to the point where it exceeds the velocity of free-fall of the particle, fluidization occurs; this is called *fluidized-bed freezing*. Fluidized bed freezer system operates with direct contact between refrigerant and the product and are used to freeze particulate foods such as peas, cut corn, diced carrots, and strawberries. Fluidized bed freezing is a modification of air-blast freezing. Solid food particles ranging in size from peas to strawberries can be fluidized by forming a bed of particles 1-5 in. Particulate foods are fed by a shaker onto a porous trough. The food is pre-chilled and high velocity refrigerated air fluidizes the product, freezes it and moves it in continuous flow for collection and packaging. An air velocity of at least 375 lineal ft/min is necessary to fluidize suitable particles, and an air temperature of about –34°C is common. freezing time varies with conditions, some representative times for various products are listed in Table 1.

Product	**Time to reduce temperature from 21°C to –18 °C, min**
Peas	3-4
Diced carrots	6
Cut green beans	5-12
Strawberries	9-13
French fried potatoes	8-12
Fish fillets	30

Best results are obtained with Fluidized bed freezing the products that are small and uniform in size (e.g., peas, limas, cut green beans, strawberries, whole kernel corn, brussel sprouts).
The advantages of fluidized bed freezing as compared to conventional air-blast freezing are:
• More efficient heat transfer and more rapid rates of freezing
• Less product dehydration and less frequent defrosting of equipment
• Short freezing time is apparently responsible for the small loss of moisture.

A major disadvantage of fluidized bed freezing is that large or non- uniform products cannot be fluidized at reasonable air velocities

Immersion Freezing
The immersion freezer consists of a tank with a cooled freezing media, such as glycol, glycerol, sodium chloride, calcium chloride, and mixtures of salt and sugar. The product is immersed in this solution or sprayed while being conveyed through the freezer, resulting in fast temperature reduction through direct heat exchange.
Direct immersion of a product into a liquid refrigerant is the most rapid way of freezing. The solute used in the freezing system should be safe without taste, odour, colour, or flavour, and for successful freezing, products should be greater in density than the solution.
Immersion freezing systems have been commonly used for shell freezing of large particles due to the reducing ability of product dehydration when the outer layer is frozen quickly. A commonly seen problem in these freezing systems is the dilution of solution with the product, which can change the concentration and process parameters. It has the following advantages:
● There is intimate contact between the food or package and the refrigerant; therefore, resistance to heat transfer is minimized.
● Although loose food pieces can be frozen individually by immersion freezing and air freezing, immersion freezing minimizes their contact with air during freezing, which can be desirable for foods sensitive to oxidation. **For direct immersion freezing, the refrigerant used must have the following properties:**
1. It should be Non-toxic.
2. It should be Clean.
3. Free from frozen tastes, odour/bleaching agents.

Cryogenic freezing Cryogenic freezing is a type of freezing which requires extremely low temperatures, generally below -238 Fahrenheit (-150 Celsius) through direct contact with liquefied gases such as nitrogen or carbon dioxide.
This type of system differs from other freezing systems since it is not connected to a refrigeration plant; the refrigerants used are liquefied in large industrial installations and shipped to the food-freezing factory in pressure vessels. The refrigerants used at present in cryogenic freezing are liquid nitrogen and liquid carbon dioxide. In the former case, freezing may be achieved by
● immersion in the liquid,
● spraying of liquid, or

- circulation of its vapor over the product to be frozen.

Low initial investment and rather high operating costs are typical for cryogenic freezers. Liquid nitrogen (LN) is used in many cryogenic freezers. The product is placed on a conveyor belt and moved into the insulated chamber, where it is cooled.

Liquid Nitrogen Freezers-Liquid nitrogen, with a boiling temperature of -196 °C at atmospheric pressure, is a by-product of oxygen manufacture. The refrigerant is sprayed into the freezer and evaporates both on leaving the spray nozzles and on contact with the products. The system is designed in a way that the refrigerant passes in counter current to the movement of the products on the belt giving high transfer efficiency. Typical food products used in this system are fish fillets, seafood, fruits, and berries.**Advantages of LN freezing are as follows:**

- Dehydration loss from the product is usually much less than 1%
- Oxygen is excluded during freezing
- Individually frozen pieces of product undergo minimal freezing damage
- The equipment is simple, suitable for continuous flow operations, adaptable to various production rates and product sizes, of relatively low initial cost, and capable of high production rates in a minimal space.
- The only disadvantage of LN freezing is high operating cost, and this is attributable nearly entirely to the cost of LN.

Liquid carbon dioxide freezers-Liquid carbon dioxide exists as either a solid or gas when stored at atmospheric pressure. When the gas is released to the atmosphere at -70 °C, half of the gas becomes dry-ice snow and the other half stays in the form of vapor. This unusual property of liquid carbon dioxide is used in a variety of freezing systems, one of which is a pre-freezing treatment before the product is exposed to nitrogen spray

Indirect Contact Systems

Plate Freezers: The most common type of contact freezer is the plate freezer. In this case, the product is pressed between hallow metal plates, either horizontally or vertically, with a refrigerant circulating inside the plates. Pressure is applied for good contact as schematically. In some cases, plate systems may use single plates in contact with the product. This type of freezing system is only limited to regular-shaped materials or blocks like beef patties or block-shaped packaged products. As would be expected, these systems are less efficient, and they are costly to acquire and operate.

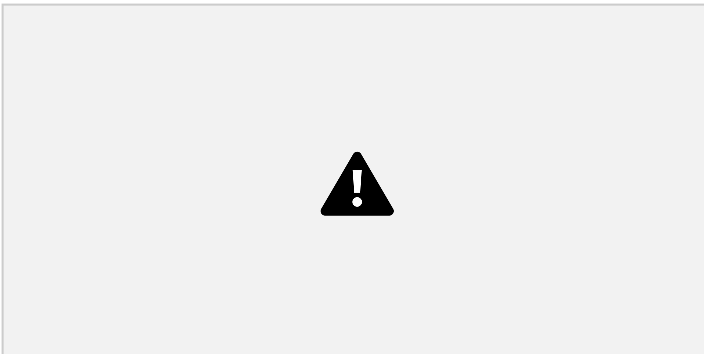


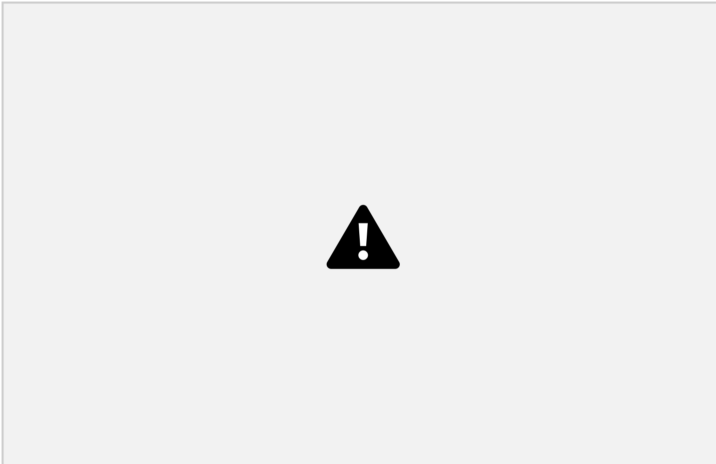
Plate-freezing systems can be operated as a batch or continuous system.

Air or still freezing: - Air freezing is the oldest of the freezing methods. The equipment is the simplest. The food is simply placed in an insulated cold room at a temperature maintained in the range of –15 °C to –29°C. This method is different from the air-blast freezing, which employs air velocities. Although there is some air movement by natural convection, in some cases gentle air movement is promoted by placing circulating fans in the room. This method is also referred as *still air freezing* or *sharp freezing*. It is similar to the freezing conditions that exist in home freezers except that temperatures are low i.e. –18 to –30°C.

Air-Blast freezing: An improved version of the still air freezer is the forced air freezer, which consists of air circulation by convection inside the freezing room. Air blast freezing is the process of taking a product at a temperature (usually chilled but sometimes at ambient temperature) and freezing it rapidly, between 12 and 48 h, to its desired storage temperature which varies from product to product (e.g. fish = −20 °C, beef = −18

°C). These freezers operate at temperatures of –30 to –45°C, with forced air velocities of 10-15 m/sec. Food is frozen as batch to tunnels through which carts or belts may be moved continuously. Particulate unpackaged foods, such as loose vegetables are fed onto the moving belt when speed is adjustable according to the required freezing time. In other designs, food moves on trays, in a vertical direction. Trays of particulate products such as peas or beans automatically move upward through a cold air blast.
This freezing process allows the formation of small crystals of ice inside the cell of the product, in order to avoid cellular damage. The air flow is normally counter-current.

There are four important points to consider in efficient operation of air blast freezing:
1. Air temperature of the freezer should be -10°F (-23°C) or preferably lower. Typically, the temperature is -30 to -40°F (-34 to -40°C).
2. Air velocity should be 1,000-2,000 ft/min (305-610 m/min) or higher.
3. Product should not be transferred to the still-air storage room until the product has attained 0°F (- 18°C).
4. A stacking arrangement on pallets should be used that enables cold air to contact all cases.



Scrapped-surface heat exchanger-The food contact areas of a scraped – surface cylinder are fabricated from stainless steel, pure nickel, and hard chromium plated nickel, or other corrosion resistant material. The inside rotor contains blades that are covered with plastic laminate or molded plastic. The rotor speed varies between 150 and 500 rpm. The cylinder containing the product and the rotor is enclosed in an outside jacket. The cooling medium is supplied to the outside jacket. Commonly used media include brine or a refrigerant such as Freon.
The scraped-surface heat exchanger ensures efficient heat exchange between the slurry and the cold surface. Freezing systems for liquid foods can be batch or continuous.
In the case of ice-cream freezing, the system is designed with facility for injection of air into the frozen slurry to achieve the desired product consistency. In a continuous freezing system for liquid foods, the basic system is a scraped -surface heat exchanger using refrigerant during phase change as the cooling medium. The rotor acts as a mixing device, and the scraper blades enhance heat transfer at the heat-exchange surface.

ADVANTAGES OF FROZEN FRUITS AND VEGETABLES

- The fresh vegetables and fruits closely resemble their frozen counterparts in freshness, since the metabolic activities are arrested to such an extent that all the enzymes are inactivated and microorganisms are under control.
- The taste, flavour and colour of fruits and vegetables are preserved to a maximum.
- They have high nutritive value since the retention of nutrients is maximum.
- Since frozen vegetables have already been subjected to a heat treatment, they require less time for cooking thus saves considerable time in kitchen and also saves fuel.
- Greater convenience in handling and preparation.
- Freezing is a suitable choice for preserving fruit juices containing anthocyanin and carotenoid pigments since the retention of pigments is maximum.
- They offer more hygienic food
- Cent percent edible portion of food of food in each package
- Since the degradative effect of heat treatment is bypassed in this, the method of freezing can retain the pigment of such fruit juices and concentrates in its best form
- Freezing can also serve as an intermittent technology for preserving commodities in bulk and supplying in a different form when demand arises eg peas can be frozen in bulk quantities and during

demand defrosted put in a brine solution packed in flexible pouches and circulated in market whenever required.

- Value for money especially off-season
- No pollution problem in consuming areas
- The waste collected during freezing can be utilized for production of value-added products.

Limitations

1. Some water-soluble nutrients may be lost during freezing as the process involves blanching in boiling water.
2. Users of quick-frozen foods need to invest on freezers to maintain the quality of the product till used. This adds to the cost of the product.
3. Proper freezing transport facilities have to be developed for each product.
4. Quick freezing can be handled at the industrial level because it involves specialized freezing equipment, technological know-how, strict quality control which would not be feasible on a small scale.
5. Sales markets have to be established in all markets with refrigerated display cabinets.

QUALITY AND PHYSICAL CHANGES IN FROZEN FOODS

When the food is frozen it undergoes number of quality and physical changes. Lets us see what they are.

Concentration Effects

Damage due to concentration results in

1. Gritty, sandy texture of food due to precipitation of solutes out of solution.
2. Salting out at proteins effect due to solutes remaining in concentrated solution.
3. Drop in pH drop causing proteins to coagulate.

Ice Formation

There are 2 types of fluids viz., Extra-cellular fluid (EF) and Intracellular fluid (IF). The concentration of salts and other soluble products is higher within the cells than outside. When the product is frozen, the first ice-crystals are formed outside the cells. The cells lose water by diffusion through the membrane. As the cells lose water, the remaining solution within the cell becomes more concentrated and their volumes shrink causing the cell wall to collapse.

The large ice-crystals formed outside the cell wall occupy a larger volume than the corresponding amount of water and therefore, will execute a physical pressure on the cell wall. When the pressure becomes high, it can damage the cell wall and lead to release of intracellular fluid (Drip loss). If the freezing rate is high, ice-crystals are formed outside the cells. Only at very high freezing rates, small crystals are formed uniformly throughout the tissue, both externally and internally with regard to the cells.

Freeze burn

It refers to a defect which develops during frozen storage. Moisture loss due to sublimation from surface leads to discoloration in form of patches of light coloured tissues. This can be controlled by humidification or lowering of storage temperature or better packaging.

Freeze Cracking

Generally, light freezing rates lead to small ice crystals and to better quality food systems. However, some products may crack when submitted to high freezing rates as in cryogenic fluids. This is particularly seen in mango slices frozen by liquid nitrogen. Pre-cooling prevents freeze cracking.

Moisture Loss

Moisture loss, or ice crystals evaporating from the surface area of a product, produces freezer burn. We have already discussed what freezer burn is. This surface freeze-dried area is very likely to develop off flavours. Packaging in heavyweight, moisture-proof packaging material will prevent freezer burn.

Drip Loss

Formation of ice crystals causes a physical pressure on the cell wall. When the pressure becomes high, it can damage the cell wall and lead to release of intracellular fluid. This is called drip loss.

Rancid Flavour

In frozen products chemical changes can take place due to this development of rancid oxidative flavours may develop in frozen product. This problem can be controlled by using a wrapping material which does not permit air to pass into the product. It is also advisable to remove as much air as possible from the freezer bag or container to reduce the amount of air in contact with the product.

PACKAGING AND STORAGE

A wide variety of materials have been used for packaging of frozen foods including plastics, metals and paperboards. Polyethylene (PE), low density Polyethylene (LDPE) and High density Polyethylene (HDPE) are commonly used for packaging of IQF foods i.e. fruits, vegetables and fish. Materials are easy to seal and can be easily printed. LDPE is also easily available and cheap. HDPE can tolerate temperature in excess to 100°C. Both HDPE and LDPE however provide relatively poor barrier protection from oxygen. Polyester tetra phthalate (PET) is another common material used. The trays of the material are suitable for reheating in conventional and microwave oven with stability at temperature in excess of 250°C. However the materials are expensive and can become brittle at freezer temperature. Polystyrene (PS) is also general plastic material used for frozen food applications. Commercial storage of frozen storage of frozen products is usually done in deep freezers at –18 to –20°C.

STORAGE AND TRANSPORTATION OF FROZEN PRODUCE

To preserve quality and safety in frozen foods, strict temperature requirements are must during storage, handling, distribution, and retail display and consumer storage. It is recommended that food temperatures are maintained at –18°C or colder, although exceptions for brief periods are allowed during transportation or local distribution when –15°C is permitted. Also, retail display cabinets should be at –18°C, to an extent consistent with good storage practice, but not warmer than–12°C. The transport and distribution sections of the chill chain are particularly important to control in order to ensure both safety and quality. It is important to check temperature of foods at each point within the chill chain from storage and transportation.

Factors Determining Freezing Rate

Food Composition- Like metals and other materials, food constituents have different thermal conductivity properties which change with temperature.

The greater the conductivity, the greater the cooling and freezing rate. It should also be noted that fat has a much lower thermal conductivity than water, and air has a thermal conductivity far less than that of water or fat. That why the food rich in fat will freeze in more time as compare to food which contain less fat.

Food thickness: - the freezing point of food also depends upon the thickness of food items. When the food items are thick their freezing time is more. But when the food item is thin their freezing time is low.

Air velocity: - if the velocity of air circulated to freeze the stored food is faster the freezing of food items.

Packaging: -the packaging of the food increases the freezing of the food items. Further the thickness of the packaging material also affected the freezing time. If the packaging material is thick then freezing time will be more and if the packing material is thin the freezing time will be less.

Contact between food and cooling medium: - if the contact between the food and cooling medium is more than freezing time will be less because more heat will transfer from food to cooling medium due to greater area of contact between food and cooling medium.

KEY WORDS

Freezing point: Temperature at which the liquid congeals into the solid state at a given pressure and temperature.

Refrigerated storage: Refers to storage temperatures above freezing point of water i.e. about 16 to –2°C.

Quick freezing: Quick freezing is defined as the process where the temperature of the food passes through the zone of ice crystal formation in 10 minutes or less. The process removes quick removal of water and small ice crystals are formed in the process.
Slow freezing: Slow freezing involves slow removal of water and process may take 3-72 hours.
Fluidized bed freezing: A method of freezing used for particulate itemssuch as peas, diced carrots, corn and berries. Thefreezer employs a bed with a perforated bottomthrough which refrigerated air is blown verticallyupwards.
Blanching: Blanching is a common heat pre-treatment commonly used before processing most vegetables. The main aim is to inactivate enzymes responsible for deterioration in food.
Sublimation: The change of state from ice to water vapour or water vapour to ice. Unpackaged frozen material changes to gaseous form e.g. dry ice (frozen carbon dioxide) when exposed to extreme cold air.
Dehydro-freezing: Is pre-treatment given prior to freezing, involving partial removal of water

Freeze burn: It refers to a defect which develops during frozen storage. Moisture loss due to sublimation from surface leads to discoloration in form of patches of light coloured tissues. This can be controlled by humidification or lowering of storage temperature or better packaging.

Antifreeze: Chemical substances that added to a liquid to lower its freezing point. These chemicals prevent freezing and are commonly used in coolants for aeroplanes and automobiles.

Cool storage: The temperature in cool rooms where surplus food is stored is usually around 15 ^{o}C. Enzymatic & microbial changes in the foods are not prevented but slowed down considerably. Root crops, potatoes, onions, apples and similar foods can be stored for limited periods.

Cold store or chilling (0 to 5^{o}C): Chilling temperatures are obtained by mechanical refrigeration. Fruits, vegetables and their products can be preserved for a few days to many weeks. The best storage temperature for many foods is slightly above 0^{o}C but this varies with the product. Besides temperature, the relative humidity can affect the preservation of the food.
Commercial cold storages (temp.2-5 ^{o}C; R.H 90-100%) with automatic control of temperature are used for storage of semi-perishable foods such as potatoes and apples and made their availability throughout the year. The growth of bacteria, yeasts, and moulds, and rate of all chemical reactions is slow at or below 10^{o}C, and becomes slower the colder it gets.

1 tonne of refrigeration is the rate of heat removal required to freeze a metric ton (1000 kg) of water at 0°C in 24 hours.

Preservation by High Temperature :-Pasteurization, Sterilization, and Canning: their Definition, Method, advantages and disadvantages

PASTEURIZATION

Pasteurization is a comparatively low order of heat treatment, generally at a temperature below the boiling point of water. The more general objective of pasteurization is to extend product shelf-life from a microbial and enzymatic point of view. This process is named after the French chemist **Louis Pasteur**, who devised it in 1865 to inhibit fermentation of wine. He discovered that the destruction of bacteria can be performed by exposing them to certain minimum temperature for certain minimum time and the higher the temperature the shorter the exposure time required. In this process, all of the bacteria (such as *E.coli, Lysteria*, and *Salmonella)* are not destroyed; but there concentration reduces very low. Refrigeration keeps the bacteria from further growth, very low. The term pasteurization as applied to market milk today refers to process of heating every particle of milk to at least 63° C for 30 minutes or 72° C (161°F) for 15 seconds (or the temp-time combination which is equally efficient) in an approved and properly operated equipment.

Pasteurization : A process of heating every particle of milk or milk product to specified temperature and holding at that temperature for specified period followed by immediate cooling and storage at low temperature.

OR

when food is heated in containers or by other method to a temperature below 1000 C for a definite period of time, the process is known as pasteurization

Temperature/time treatment in pasteurization

Food Product	**Temp (°C)**	**Time (Seconds)**
Milk	72	15
Tomato Juice	118	60
Fruit Juice	88	15
Soft Drink	95	10

Pasteurization temperature and time will vary according to:
nature of product; initial degree of contamination;
Pasteurized product storage conditions and shelf life required

Aim of Pasteurization

- It inactive the food enzymes like blanching.
- it kills the pathogenic organisms and inactive the spoilage micro-organisms
- It increases the shelf life of the food product

Pasteurization is frequently combined with another means of preservation - concentration, chemical, acidification, etc. Blanching is a type of pasteurization usually applied to vegetables mainly to inactivate natural food enzymes. Depending upon time and temperature treatment there are three kinds of pasteurization processes.

Low Temperature Long Time (LTLT)

In LTLT the time and temperature generally 62.8 °C for 30 minutes is used but may vary between 63° to 66° C or more, depending on holding time. This process is also called batch type pasteurization and now a day this process is not used because of high energy and time loss.

In LTLT pasteurization it is possible to define three phases:
heating to a fixed temperature;
maintaining this temperature over the established time period
(= pasteurization time);
Cooling the pasteurized products: natural (slow) or forced cooling.

Advantages of LTLT
Low initial cost

Disadvantages of LTLT
Transfer of heat very slow.
Processing cost is high
Require more space for increasing capacity.
Packing cannot be start during pasteurization

This is a typical batch method where a quantity of milk is placed in an open vat and heated to 63°C and held at that temperature for 30 min. Sometimes filled and sealed bottles of milk are heat-treated in shallow vats by that method and subsequently cooled by running water.

High Temperature Short Time (HTST)

In HTST pasteurization generally 71.7° for 15 seconds is used but according to the nature of product the temperature may very between 85° to 90° C or more, depending on holding time.

Typical temperature/time combinations are as follows:
88° C for 1 minute
100° C for 12 seconds
121°C for 2 seconds.

Advantages of HTST
Less floor space is required
lower initial cost
milk packing can start as soon as pasteurization begin
easily cleaned and sanitized
lower operating cost
Pasteurization capacity can be increased at nominal cost.

Disadvantages of HTST

The system is not well adapted to handling small quantities of removal liquid milk product.
Gas kit require constant attention for possible damage and lake of sanitation
complete damage is not possible

Ultra-High Temperature (UHT) Processing Treatments

In this method fluid is exposed to a brief, intense heating, normally totemperatures in the range 135-140 °C but for a very short time, a second orless. The treatment kills all microorganisms. This is method is not for very heat sensitive products because this much of temperature can spoil theproduct. This method is used mainly for coffee creamers and boxed juices. After this is done,there is no need to refrigerate, because it sterilizes the product. Sometimes theproducts can have a "cooked" taste that can be detected after being brought tosuch a high temperature.
Sterilization

Sterilization: A process to heat food product to a specific temperature for a specific time to kill the most heat resistant spore-forming organism.

Sterilization is a process of heat application above 100°C, by sterilization we mean complete destruction of micro-organisms. Because of the resistance of certain bacterial spores to heat, this frequently means a treatment of at least 121° C (250° F) of wet heat for 15 minutes or its equivalent by using steam under pressure. It also means that every particle of the food must receive this heat treatment. If a can of food is to be sterilized, then keeping it at 121° C or retort for the 15 minutes will not be sufficient because of relatively slow rate of heat transfer through the food in the can to the most distant point. In such cases time needs to be increased.

At 121° C temperatures the spores of the heat resistant bacteria are quickly killed. The longer is the heat treatment time at lethal temperatures, the larger is the number of killed microorganisms. At higher temperature, the shorter is the time required to kill microorganisms and lower is heat-included damage to food products. But in the case of canned food keeping it at 121° C or retort for the 15 minutes will not be sufficient because of relatively slow rate of heat transfer through the food in the can to the most distant point. In such cases time needs to be increased.

Theoretically, absolute sterility does not exist. In commercial practice not all cans of food are sterile. However, they usually do not spoil because conditions in the container are not favorable for the growth of concerned microorganisms. The pH may be too low or absence of oxygen. Therefore, the term processing is highly suitable than the term 'sterilization' applied to canned foods.

The foods products low in acid and often high in protein and contain spore forming bacteria are difficult to sterilize. The acidity of fruits and tomatoes greatly lower the death or sterilizing temperature, which usually explains why acid fruits are easily sterilized.

This process wills make the treated product safely preserved at room temperature.

Effect of commercial sterilization

The destruction of nutrients the thermal process is dependent on
i) time temperature treatment used as the basis of the process
ii) rate of heat transfer into the product.

The commercial developments have focused primarily on increasing the rate of heat transfer into the product. Hence, agitated retorts such as the orbitort, steritort, flame sterilizer and hydrostatic cooker have been developed.

It has been observed that retention of vitamin C in tomato juice is improved when processing is conducted at a HTST condition.Under HTST conditions nutrient retention may be greatly enhanced. HTST aseptic canning also results in a significant improvement in organoleptic qualities i.e. colour, taste and aroma. In an evaluation of HTST aseptic processing, it was found that thiamin retention was significantly greater in HTST products than in conventionally canned and retorted products.

It is a misconception to think that commercially sterile products remain unchanged during storage. This is not the truth. Organoleptic and nutrient changes do occur during storage, the extent of the changes being dependent on the time and temperature of storage. It has been observed that low temperature storage results in an improvement in nutrient retention.

Canning

There are several methods of preservation of fruits and vegetables and canning is one of them. It is an important method of food preservation by heat. In this process, the foodstuff (fruits & vegetables) are placed in containers, and sterilized by placing them in hot water or steam. Canning is also known as appertizing in honour of its inventor.

Canning: is defined as preservation of foods in sealed containers and usually implies heat treatment as the principal factor in the prevention of spoilage.
Or
the process of preserving food by sterilization at >100_0 C and cooking in a sealed metal can, which destroys bacteria and protects from contamination.

History of Canning

The canning process dates back to the late 18th century in France when the Emperor Napoleon Bonaparte, concerned about keeping his armies fed, offered a cash prize to whoever could develop a reliable method of food preservation. Nicholas Appert conceived the idea of preserving food in bottles, like wine. After 15 years of experimentation, he realized if food is sufficiently heated and sealed in an airtight container, it will not spoil. Peter Durand, took the process one step further and developed a method of sealing food into unbreakable tin containers, which was perfected by Bryan Dorkin and John Hall, who set up the first commercial canning factory in England in 1813. More than 50 years later, Louis Pasteur provided the explanation for canning's effectiveness when he was able to demonstrate that the growth of microorganisms is the cause of food spoilage.

CANNING PROCESS FOR FRUITS AND VEGETABLES

Canning is defined as the preservation of foods in the sealed containers and usually implies heat treatment as the principal factor in prevention of spoilage. Mostly the canning is done in tin cans but other containers like glass, plastics, etc. The fruits and vegetables used for canning should be as fresh as possible so that their quality could be retained. Fruits should be mature, firm ripe and free from all defects, while vegetables should be usually tender.

Principles

1. Destruction of spoilage organisms within the sealed containers by application of heat,
2. To improve the texture, flavour and appearance by cooking, and
3. To stop recontamination of food during storage.

Selection of fruits & vegetables

Sorting & Grading

Washing

Peeling

Cutting

Blanching

Filling

Syruping/Brining

Lidding /Clinching

Exhausting

Seaming

Processing

Cooling
Storage

Selection of Fruits and Vegetables

We should select the fresh good quality fruits and vegetables for canningbecause quality of canned product is dependent on the quality of rawmaterial. Fruits should be firm, mature and uniformly ripe. Over-ripe,insect infected and diseased fruits and vegetables should be rejected.Unripe and immature fruits should be rejected because they generallyshrivel and toughened on canning. Vegetables should be tender. Fruitsand vegetables should be free of dirt.

Sorting and Grading
We should see that any spoiled, blemished, injured fruit or vegetable bediscarded. Raw material should be sorted based on maturity andripeness. Fruit and vegetables should be graded according to size andcolour to obtain uniform quality of canned product. Grading can be doneby hand or by machines. Screw type and roller type grader are generallyused.Fruits like berries, cherries, grape and plum are graded whole, whilepeach, pear, apricot, mango, pineapple, etc., are generally graded aftercutting into pieces.

Washing
Fruits and vegetables should be washed with water thoroughly. Washing will remove dust, dirt and any sprayed chemical residue. Anymicroorganism over the surface of the fruits or vegetables are alsowashed out. Water used for washing may be cold or hot. We mayemploy chlorine (150ppm) or potassium permanganate (dilute solution)in water to disinfect fruits and vegetables. Fruits and vegetables aregenerally soaked in water tank before washing by hand. They can bewashed by spraying water, which is the most effective method.

Peeling
Washed fruits and vegetables are prepared for canning. The fruits andvegetables are peeled by hand with knife or machine, heat treatment orlye solution. Lye is a solution of caustic soda. For example, peaches andpotatoes are scaled in steam or boiling water and put in cold water tosoften and loosen or cracking of skin. Later the skin can easily beremoved by hand or pressure spray of water.In case of lye peeling of fruits and vegetables, e.g., peaches, apricots,orange and sweet potatoes are dipped in boiling lye (1-2% caustic soda)for ½ to 2 minutes. Any trace of alkali is removed by washing fruits andvegetables in running cold water; sometimes they are also washed inwater containing 0.5 per cent citric acid or hydrochloric acid.

Cutting
We should cut the fruits and vegetables depending upon the requirementlike slice, dice, finger etc either by knife or by machine. At the sametime seed, stone and core are also removed by special coring knife.

Blanching
In blanching operations, the prepared fruits and vegetables are kept inboiling water or exposed to steam for 2 to 5 minutes followed by coolingin running cold water. The time and temperature of blanching varydepending on the type of raw material. Inactivation of peroxidaseenzyme is used as an index adequacy of blanching.
The purposes ofblanching are:
(1) to inactivate the enzymes, which cause discolorationand off-flavour
(2) to reduce the volume by shrinkage, making theirpacking easier
(3) to reduce the microbial load on raw materials
(4) toenhance the green colour of vegetables like peas and spinach,
(5) toremove undesirable acids and astringent taste of the peel resultingimproved flavour, and (6) to remove occluded gases for reducing strainon the seam of can during processing.
Filling
Tin cans are used as containers for canning. The cans can be openedfrom any end as they are called open top sanitary can. Cans are washedwith hot water. Prepared fruits and vegetables are filled into cans eitherby hand or by machine. Plain cans are used generally, although in caseof coloured fruits like black grapes, red plum, strawberries, etc.,lacquered cans are employed.In case of canned fruits, the drained weight should not be less than 50%and for berry fruits not less than 40%. Similarly, for canned vegetablesthe drained weight should not be less than 55% but in case of tomatoeslimit is the 50%. Therefore, fruits and vegetables are filled about 60 percent of the filling capacity of a can.

Syrup
A solution of sugar in water is called syrup. Generally, the fruits arecovered with sugar syrup. Cans are filled with hot (79°–82°C) sugarsyrup, leaving a headspace of 0.3 to 0.5cm. Syrup of 10° to 55° Brix(per cent sucrose) is generally used. We can prepare sugar syrup of 20°Brix by dissolving 250 g sugar in one-liter water and of 50oBrix bydissolving one kg of sugar in one litre water. Sometimes citric acid andascorbic acid

are also mixed with the syrup to improve flavour andnutritional value, respectively. The purpose of adding syrup to fruits is
(1) to improve taste
(2) to fill up the interspaces in can
(3) tofacilitate further processing.

Brining
Brine is a solution of common salt in water. Brine is used in canning of vegetables. A brine of 1 to 3% salt is used at 79°-82°C, leaving a headspace of 0.3 to 0.5 cm in the can. The objectives of brining are to improve the taste of vegetables and to facilitate further processing by filling the interspaces of vegetables in the can.

Lidding or Clinching
Now the filled cans are covered loosely with the lid before exhausting. It has some disadvantages such as spilling of the contents and toppling of the lids. In modern canning, lidding has been replaced by clinching operation. In this case, lid is partially seamed. The lid remains sufficiently loose to permit the escape of gases, air and vapour formed during exhausting operation.

Exhausting
There are respiratory gases and air remains in the cans, which are to be removed before processing. The method of removing these gases is known as exhausting. Containers are exhausted by heating or mechanically. In heat exhausting, the cans are passed through a tank of hot water or exhaust box under steam. The fruit cans are exhausted at 82 to 100°C for 7-10 minutes or until temperature at the centre of the can reaches 74°C. The vegetable cans are exhausted at 90 to 100°C for 7-10 minutes or until temperature at the centre of the can reaches 77°C. The proper exhausting reduces the strain on the seam of the can. The time and temperature of exhausting vary with the size and contents of can, but it should be sufficient to ensure a vacuum of 12 to 15-inch Hg in processed and cooled can.

Sealing or Seaming
After exhausting, the cans are sealed by double seaming machine andthe method is called seaming. In sealing lids on cans, a double seam iscreated, and the method of sealing or closing is also known as seaming.

Processing
Process of heating and cooling of canned food to inactivate bacteria and to preserve food is also called as commercial sterilization. Many bacterial spores are heat resistant, which can only be killed either by very high or by very low temperature treatment or prolonged cooking. Such drastic treatment, however, affects the quality of food. Thus, processing time and temperature should be adequate to eliminate all bacterial growth. We must not over-cook the canned foods otherwise it will spoil the flavour, appearance and texture of the product. All fruits and acid vegetables can be processed satisfactorily at a temperature of 100°C, i.e., in boiling water. The acid present in fruits and acid vegetables retards the growth of bacteria and spores. These bacteria and spores do not thrive in heavy sugar syrups, which are normally used in canning fruits. Vegetables, generally non acidic (except tomato and rhubarb), are processed at a higher temperature of about 115 to 121°C. Bacterial spores usually do not grow below pH 4.5 as you have read in previous chapters. We, generally process the canned products having pH less than 4.5 in boiling water but products with pH higher than 4.5 require processing at 115 to 121°C. The higher temperature can be obtained by processing in a retort under a pressure of 0.70 to 1.05 kg/cm2 (10 to 15 lb/sq. inch). The centre of can should attain these high temperatures. The temperature and time of processing vary with the size of the can, the larger the can, the greater is the processing time. Fruits and acid vegetables are generally processed in open type cookers, continuous non-agitating cookers and continuous agitating cookers. The open cookers are galvanized iron tank of desired capacity. Sealed cans are placed in iron crates and immersed in the tank containing boiling water. In continuous cookers, the cans travel in boiling water in crates carried by overhead conveyors. In continuous agitated cookers, the cans are rotated by special mechanical devices to agitate the contents of the cans. Agitation reduces the processing time considerably. The non-acid vegetables are processed under steam pressure in closed retorts. The sealed cans are placed in the retort, keeping the level of water 2.5 to 5.0 cm above the top of the cans. The cover of the cooker is then screwed down tightly and the cooker is heated

by steam to the desired temperature. The period of processing (sterilization) should be counted from the time the water starts boiling or steaming. After heating for the required period, heating is stopped and the petcock or vent is opened. When the pressure comes down to zero the cover is removed and the cans are taken out.

Cooling

After processing, the cans are cooled rapidly to about 39°C to stop the cooking process. Cooling can be done by several methods such as

(1) immersing the hot cans in tank containing cold water

(2) spraying cold water

(3) turning in cold water into the pressure cooker,

(4) exposing the cans to air. Generally, the first method is practiced.

Cooling water may be kept sterile with 1 or 2 per cent chlorine. If canned products are not cool immediately after processing, the quality is deteriorated, e.g., peaches and pears become dark in colour, tomatoes turn brownish and become bitter in taste, while peas become mashy with a cooked taste.

Testing for Defects

Before the canned products are marketed, we should test them for any defect. The finished cans are tested for leak or imperfect seals. We should tap the top of the can with a short steel rod. A clear ringing sound indicates a perfect seal, while a dull and hollow sound shows a leaky or imperfect seal. Leaky cans should be removed from the lot.

Storage, labeling and packing

Before storage, the cans should be completely dry, small traces of moisture are likely to induce rusting. They should be stored in a cool and dry place. Storage of cans at high temperature should be avoided, as it shortens the shelf life of the product. The high temperature may lead to hydrogen swell and perforation during extended storage. The basement stores are useful, especially during summer months. The temperature in these stores is lower by about 6° to 8°C, compared to outside temperature. Before dispatch, the cans are labeled and packed either in wooden or cardboard boxes, and are ready for marketing. The cans may be stored for 1 to 2 years depending upon the type of raw materials used and the shelf life of the product.

Spoilage in Canned Fruits and Vegetables

Canned products are liable to spoilage for various reasons. Spoilage in canned food may be caused due to two reasons. Heated canned foods may undergo spoilage either due to chemical or biological reasons.

A) Spoilage due to physical and chemical changes:

1. Swell – Swell or bulge in cans caused due to the positive internal pressure of gases formed by microbial or chemical action. Hydrogen Swell – This type of swelling is due to the hydrogen gas produced by the action of food acids on the metal of the can. The swelling ranges from flipper – springer, soft swell or hard swell.
2. Overfilling – Overfilling should be avoided.
3. Faulty retort operation – It gives cans look like swells.
4. Under exhausting – It causes severe strain during heat processing.
5. Paneling – It is seen in large sized cans that the body is pushed inward due to high vacuum inside.
6. Rust – Rust is mostly seen under the label and subsequently affects the label. Cans lacquered externally do not rust.
7. Leakage – Cans generally leak due to defective seaming and nail holes.
8. Bursting – Can burst due to excess pressure of gases produced by decomposition of the food.
9. Discoloration – This may be due to enzymatic and non – enzymatic browning. Enzymatic discoloration can be avoided by placing the peeled and cut pieces of fruits and vegetables in 2% salt solution.
10. Stack burning – The contents in the can if remain hot for a long-time during storage result in stack burning. It may cause discoloration. To avoid stack burning cans should be cooled quickly to about 39oC before storage.

B) Spoilage by microorganisms

The time gap between filling and heat processing may cause microbial spoilage. If cans are not processed properly they may result in spoilage by bacteria and the spoilage is termed as "Under processed" spoilage.
***Clostridium botulinum* a Major Threat in Canned Products**
Various spoilages caused due to different microorganisms are:
1. Flat sour – The non-acid vegetables spoiled by Bacillus coagulens and Bacillus sterothermophilus.
2. Thermophilic acid spoilage – Cans swell due to production of carbon dioxide and hydrogen by Clostridium thermo-saccharolyticum.
3. Sulphide spoilage – Caused by Clostridium significance in low acid foods.

Tin Containers for canning

The cans are made of thin steel plate of low carbon content, lightly coated onboth sides with tin metal. Sometimes discolouration of the product orcorrosion of the tin plate takes place. In order to avoid corrosion, these cansare coated inside and or outside with lacquer, the process is known as"lacquering". There are two types of lacquers used.

1. Acid-resistant-Acid-resistant lacquer is golden colour enamel, cans coated with it are called R enamel or A.R. cans. The lacquered cans are used for packing fruits having water soluble colour (anthocyanins) for example raspberry, strawberry, red plum, coloured grapes, pomegranate, etc. Fruits having water insoluble colour, for example pineapple, mango, grapefruit, etc., are packed in plain cans only.

2. Sulphur-resistant – This lacquer is also of a golden colour, cans coated with it are called C. enamel or S.R. cans. These cans are used for packing pea, corn, lima beans, etc. The tin cans are supplied to the canning factory in flattened form, where they are reformed using a machine, reformer, into cylindrical shape. After that, they are flanged by using flanger, which curls the rings outwards at each end. The one end of the cylindrical can is then fixed, before filling it, using a machine known as double seamer. After filling, processing and exhausting the can, the lid is fixed using the same machine.

KEY WORDS
Canning: It is a process of preservation achieved by thermal sterilization of a product held in hermetically sealed containers
Blanching: dipping of fruits or vegetables in boiling water or exposing these to steam for a few minutes to kill enzymatic and biological activity prior to processing.
Canning: process of sealing of foodstuffs hermetically (air tight) in containers and sterilizing them by heat for long storage.
Degradation: loss of quality.
Denaturation: structural change in proteins due to effect of heat, light, changes in pH etc.
Deterioration: includes adverse changes in organoleptic quality, nutritional value, food safety, asthetic appeal, colour, texture and flavour.
Pasteurization: when food is heated in containers or by other method to a temperature below 100_0 C for a definite period of time, the process is known as pasteurization.
Or
Process of heating food product to a specific temperature for a specific time to kill the most heat resistant vegetative pathogen.
Or
Pasteurization is one type of preservation by heat mainly liquid, below boiling point for a specific time to destroy harmful bacteria.
Sterilization: A process to heat food product to a specific temperature for a specific time to kill the most heat resistant spore-forming organism.

D-value: It is also called "decimal reduction time" or "thermal death rate" and defined as time (in minutes) at a particular temperature (°C) required to kill 90 percent of a microbial population.

Spoilage microorganism: Microorganism which spoil the product by developing undesirable flavours, odours and changing food appearances or textures via microbial action.
Pathogenic: Microorganism which may infect plants, animals and man and make them sick.

Food Additives including Chemical Preservatives-Classification, functions and uses in foods

oses for spices, onions, potatoes and meat.

FOOD IRRADIATION

The exposure of food material under a lower dose of radiation which is less damaging to the food is known as irradiation.

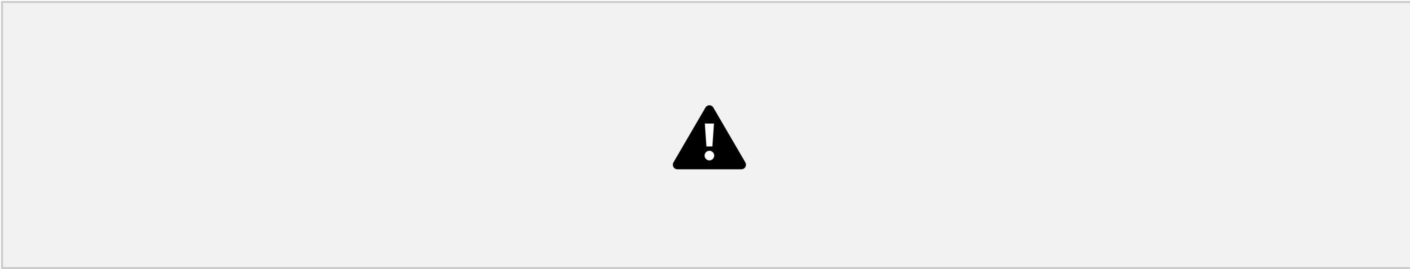
OR

Irradiation: It is the process of preserving the food by ionizing gamma-rays, X-rays and electrons. It destroys the microorganisms and inhibits the biochemical changes.

Food irradiation is a physical process like drying, freezing, canning and pasteurization. Food can be irradiated wet, dry, thawed or frozen. The irradiation of food can be considered to be a method of 'cold Sterilization', i.e. food is free of microorganisms without high temperature treatment without changing in texture and freshness of food unlike heat.
In fact you will not be able to differentiate between irradiated and non-irradiated food on the basis of color, flavour, taste, aroma or appearance. Irradiation increases the shelf life of food up-to 2 to 5 years. The product must be frozen to achieve stability without major off-flavours. As like chemical fumigants/preservatives irradiation does not leave any toxic residue in treated foods. Irradiation can be used on packed food commodities. It cannot eliminate already present toxins and pesticides in food.

In 1983, the FDA approved irradiation as a means of controlling microorganisms on spices, and in

1985, the FDA widened the allowed uses of irradiation to additional foods such as straw basics, poultry, ground beef and pork.



Purpose of food irradiation

- It retards ripening or senescence of raw fruits and vegetables
- Delay sprouting of potatoes
- Act as a fumigant to control the insect in grains, fruits and vegetables.
- Irradiation increases the shelf life of foods by destroying food spoilage microorganisms and also inhibits the activity of food enzyme.

Kinds of Ionizing Radiations

These high energy radiations can change atoms into electrically charged ions by knocking out an electron from the outer orbit and thus, are called ionizing radiations. These are represented in the equation below:

RH ------------------RH^{+} + e^{-}Ionization

RH ------------------R + H Dissociation

RH ------------------RH^{+} Excitation

But, at dose levels approved for food irradiation, these radiations cannot penetrate nuclei and thus, food can never become radioactive. Other types of radiation energy with longer wavelengths are infrared and microwaves.

Infrared radiation is used in conventional cooking. Microwaves, due to their relatively longer wavelength, have lower energy levels but are strong enough to move molecules and generate heat through friction.

Three types of ionizing radiations are approved to be used for food irradiation.

Electron beams generated from machine sources operate at a maximum energy of 10 MeV.

X-rays generated from machine sources operate at a maximum energy of 5 MeV.

Gamma rays are emitted from Co-60 or Ce-137 with respective energies of 1.33 and 0.67 million electron volts (MeV).

Electron beams

Electron beams are streams of very fast moving electrons produced in electron accelerators. For your better understanding, an electron beam generator is comparable to the device at the back of the TV tube that propels electrons into the TV screen at the front of the tube.

Electron beams have a selective application in food irradiation due to their poor penetration. They can penetrate only one and one half inches deep into the food commodity. As a result, shipping cartons (pre-packed bulk food commodities) are generally too thick to be processed with electron beams.

Electron beams are generated through machine sources, so they can be switched on or off at will and require shielding.

X-rays

X-rays are also generated through machine sources. X-rays are photons and have much better penetration and are able to penetrate through whole cartons of food products. X-rays are produced by reflecting a high-energy stream of electrons off a target substance (usually one of the heavy metals eg. a tungsten or tantalum metal plate), X-rays are generated which pass through the metal plate and penetrate the food product conveyed underneath. But, remember that this X-ray machine is a much more powerful version of the machine used in many hospitals and dental clinics. X-rays are generated through machine sources, so they can be switched on or off at will and require shielding.

Gamma rays

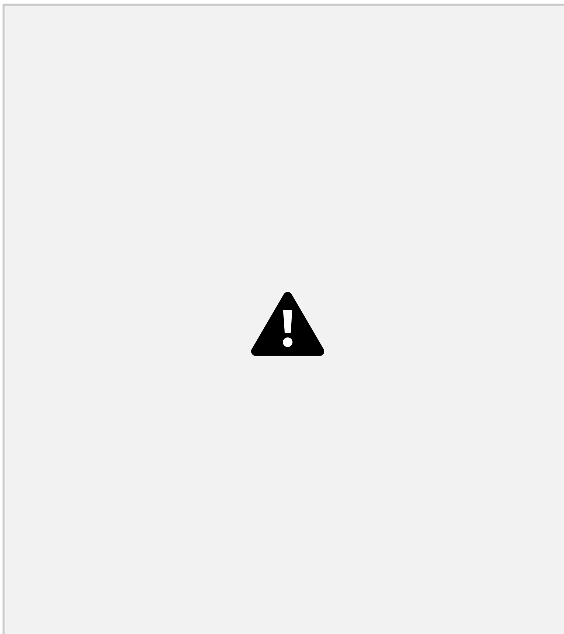
The third type of ionizing radiations approved for food processing are gamma rays that are produced from radioisotopes either Co-60 or Ce-137.
As like electron beams and X-rays, radioisotopes cannot be switched off or on at will and they keep on emitting gamma rays. Radioisotopes require shielding. Co-60 source is kept immersed under water when it is not in use and Cesium-137 is shielded in lead. Due to their continuous operation, radioisotopes need to be replenished from time to time. Gamma rays are photons and have deep penetration ability.

Units of Irradiation

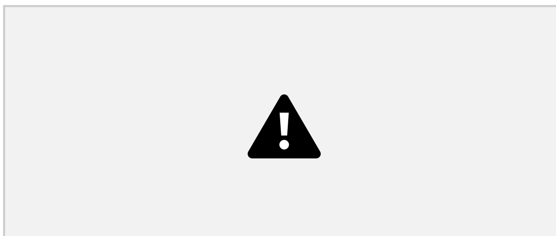
The units used to measure the effects of radiation are gray and sievert in accordance with recommendations of International Organization for Standardization (ISO). Formerly, units used for measuring radiation were the rad and the rem.
But now irradiation energy that a food absorbs is measured in a unit called gray (Gy). This is equal to one joule of energy absorbed per kg of matter being irradiated. 1 Gy corresponds to 100 rad. practically, the dose generally ranges from 50 gray to 10000 gray depending on the food. If we relate it to heat then 10000 gray or 10 kilo gray is equal to the amount of the energy required to raise temp of water by 2.4 degree c.

Mechanism of Inactivation of microorganism

Radiation is an effective means of destroying both pathogenic and nonpathogenic bacteria as well as parasites and viruses. Radiation, whether ionizing or nonionizing (i.e., a photon of energy or an electron), inactivates microorganisms by damaging a critical element in the cell, most often the genetic material. Large and complicated molecules or macromolecules, such as nucleic acids are directly or indirectly responsible for significant spoilage. Ionization slightly modifies or breaks their structure and thus prevents these molecules from functioning normally.
When potatoes are irradiated, the macromolecules responsible for initiating sprouting are ionized by the gamma rays. The very complexity of these large molecules, which makes them not active, also makes them not sensitive. One slight change to their structure, and they can no longer perform properly. Therefore, very low exposures of gamma radiation are necessary to inactivate the macromolecules responsible for sprouting.



The most important uses of irradiation are the destruction or reduction of pathogenic bacteria in foods.
The life and reproduction of these microorganisms is dependent upon their nucleic acids, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Both are very large and complicated macromolecules, they are very sensitive to ionization.
As a result, when the food is irradiated, the energy from the radiation breaks the bonds in the DNA molecules, causing defects in the genetic instructions. The effectiveness of the process depends also on the organism's sensitivity to irradiation, on the rate at which it can repair damaged DNA, and especially on the amount of DNA in the target organism:



Parasites and insect pests, which have large amounts of DNA, are rapidly killed by an extremely low dose of irradiation. It takes more irradiation to kill **bacteria**, because they have less DNA.

Viruses are the smallest pathogens that have nucleic acid, and they are, in general, resistant to irradiation at doses approved for foods.

The preservative action of ionizing radiations is in two ways,

- **Direct**
- **Indirect**

In direct action, DNA absorbs radiation and is damaged. The damage to DNA is of various types – single strand breaks (ssb), double strand breaks (dsb) or interchange bond formation.

In the indirect action, other molecules like water, Gamma rays excite and ionize water and other molecules along their track, giving rise to excitation, ionization and free radicals. When a cell is exposed to ionizing radiation, the radiation can interact with the water in a cell.

When the radiation interacts with water molecules, it can break the bonds holding the molecule together resulting in hydrogen (H^+) and hydroxyls (OH^-) ions. These ions can then combine with other ions to form substances such as hydrogen peroxide (H_2O_2) which can lead to the destruction of a cell. The OH^- ions can also attack DNA. These events contribute a great deal to the secondary effects of gamma radiation.

Process of Gamma Irradiation

- Gamma irradiation is carried out inside an irradiation chamber. The irradiation chamber is shielded by a 1.5-1.8 meter thick wall. Radiation source Co-60 is contained in slender pencil-like stainless steel casings, which in turn are contained in lead shields.
- Food products pre-packed or in bulk are placed in suitable containers and carried into the irradiation chamber with the help of an automatic conveyor.
- The conveyor goes through a concrete wall. This concrete wall serves as a shield and prevents radiation from reaching the surrounding area.
- Before irradiation of food products, activate all safety devices.
- The food containers or boxes exposed for a specific length of time that allows them to absorb a defined radiation dose.
- Gamma rays pass into the food, affect the food or target organisms present in food and leave the food.
- After radiation, proper handling and processing of food should be ensured, because irradiation cannot prevent further contamination from improper handling or processing.

Irradiators are designed with several layers of overlapping protection systems / safety devices to detect any malfunctioning of the equipment and to protect working personnel from accidental exposure to the radiations.

EFFECT OF IONIZING RADIATION ON NUTRIENTS

All processes cause changes in nutritional value of foods; even storage causes fresh foods to lose nutrients. It is well demonstrated that irradiation up to 10 kGy does not cause any significant change in the nutritional value of macronutrients, i.e., lipids, proteins and carbohydrates.

Vitamins are the most essential micronutrients present in foods. Certain vitamins like A, E, C, K and B_1 are radiation sensitive. They can be reduced by irradiation but they are similarly reduced when treated by other food processing methods.

Irradiation may convert Vitamin C (ascorbic acid) to dehydro ascorbic acid, which is another equally usable form of Vitamin C. Fat soluble vitamins like Vitamin D are radiation resistant and survive irradiation of food products.

Minerals are virtually unchanged. Iron is oxidized but the nutrient value of oxidized iron is the same as that of un-oxidized iron. Other processes like freezing, thawing, and storage have similar effects on iron.

So, the bottom line is that irradiation does not have any adverse impact on the nutritional content of a person's diet.

Any food commodity irradiated up to an overall dose of 10 kGy is safe and wholesome for human consumption.

PRACTICAL APPLICATIONS OF FOOD IRRADIATION

From a practical point of view, there are three general application and dose categories that are referred to when foods are treated with ionizing radiation

a) Low dose, up to 1 kGy

• Sprout inhibition in bulbs and tubers (0.03 – 0.15 kGy).

• Delay in fruit ripening (0.25 – 0.75 kGy).

• Insect dis-infestation and elimination of food-borne parasites (0.25 – 1 kGy).

b) Medium dose, 1 – 10 kGy

• Reduction of spoilage microbes to improve shelf-life of meat, poultry and sea foods under refrigeration (1.5 – 3 kGy).

• Elimination of pathogenic microbes in fresh and frozen meat, poultry & sea foods (3 – 7 kGy).

• Reduction of microbes in spices to improve hygiene (10 kGy).

c) High dose, 25 – 70 kGy

• Elimination of viruses.

• Sterilization of packaged meat, poultry and their products which are shelf stable without refrigeration (25 – 70 kGy).

• Sterilization of hospital diets for immuno compromised patients.

• Food for astronauts in space.

Radiation doses for

Spices

Spices, herbs and vegetable seasonings are valued for their distinctive flavours, colours and aromas. Spices are generally decontaminated by irradiation or fumigation with ethylene oxide gas (ETO).Irradiation is considered the most effective way to sanitize spices and the most countries have allowed it worldwide. Irradiation at a dose between 7.5 – 15 kGy (average dose 10 kGy) has been established to effectively control the microbiological

Delayed Ripening in Fruits

Irradiation at low dose levels (0.25 to 0.75 kGy) can delay ripening and over ripening in mature but unripe tropical fruits like banana, mango and papaya.

Sprout Inhibition in Tubers and Bulbs

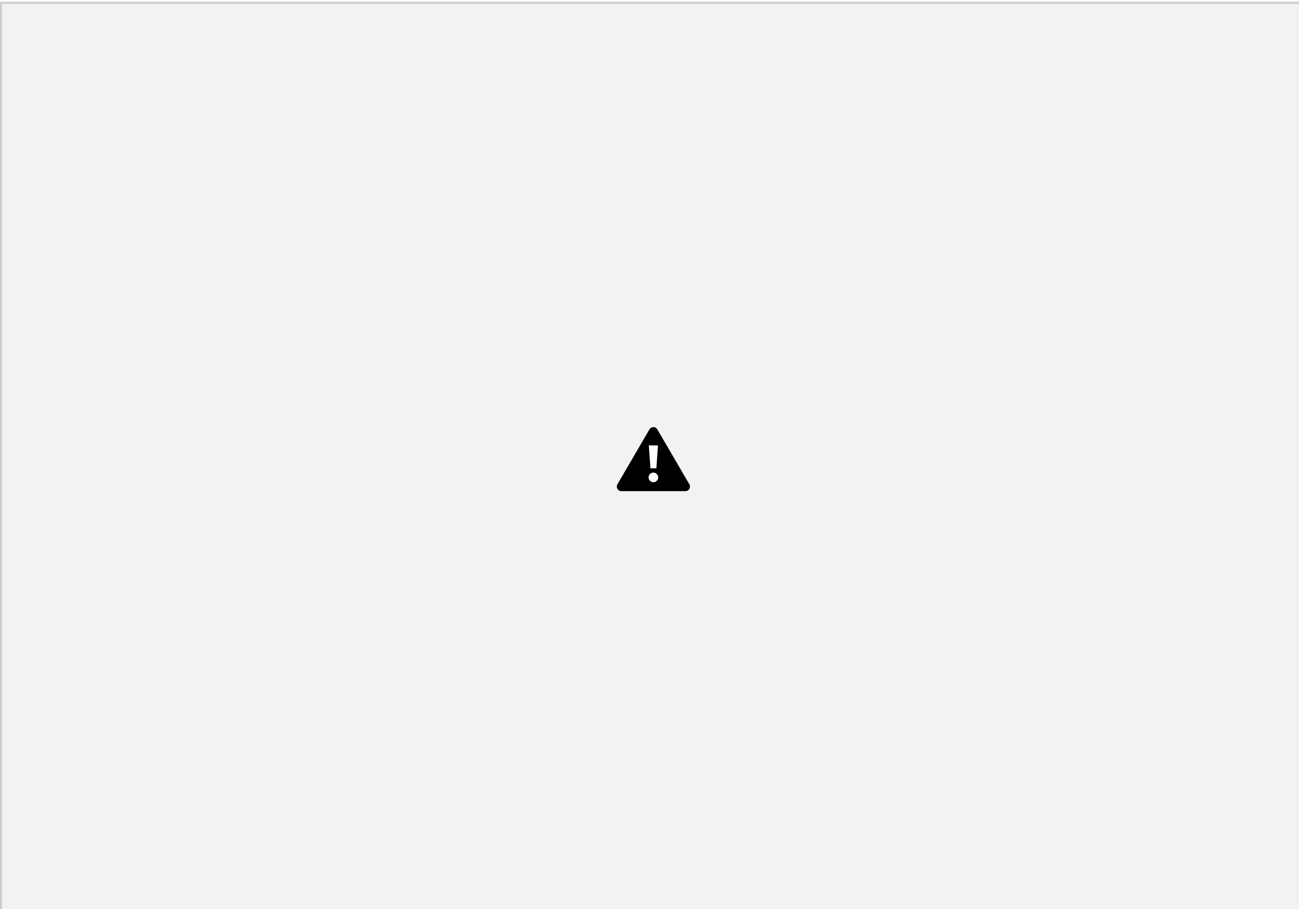
Traditionally, onions are bulk stored under ambient conditions in chawls, medas or sheds, the size and design of which varies from region to region. During prolonged storage, losses occur due to sprouting, desiccation and microbial rottage. The estimated losses are 30–50 per cent. Low ambient temperature and high humidity during rainy season promote sprouting. The losses through microbial spoilage can be reduced but sprouting can't be checked by improving ventilation. Sprouting alone causes 25–30 per cent of total losses. Sprouted onions shrivel faster due to increased water loss by transpiration. Some chemical sprout inhibitors such as maleic hydrazide and isopropyl carbamate are used in temperate countries.

Cold storage at 0-1°C with low relative humidity (65-70%) is also practiced in many temperate countries but strict temperature and humidity control is must. Moreover, cold storage is energy intensive and expensive technique.

On the other hand, irradiation at very low dose levels (0.06-0.09kGy) inhibits sprouting when properly cured bulbs are irradiated within 2-3 weeks of harvesting.

Potatoes cannot be stored more than 4-6 weeks at ambient temperature. They are stored in cold storage at 2-4°C having relative humidity 85-95 per cent. Irradiation of potatoes combined with refrigeration at 15°C can extend the storage period up to six months with minimum losses.

Sterilization of packaged meat---------25.00-70.00 kGy
Delay spoilage of meat------------------1.50–3.00 kGy

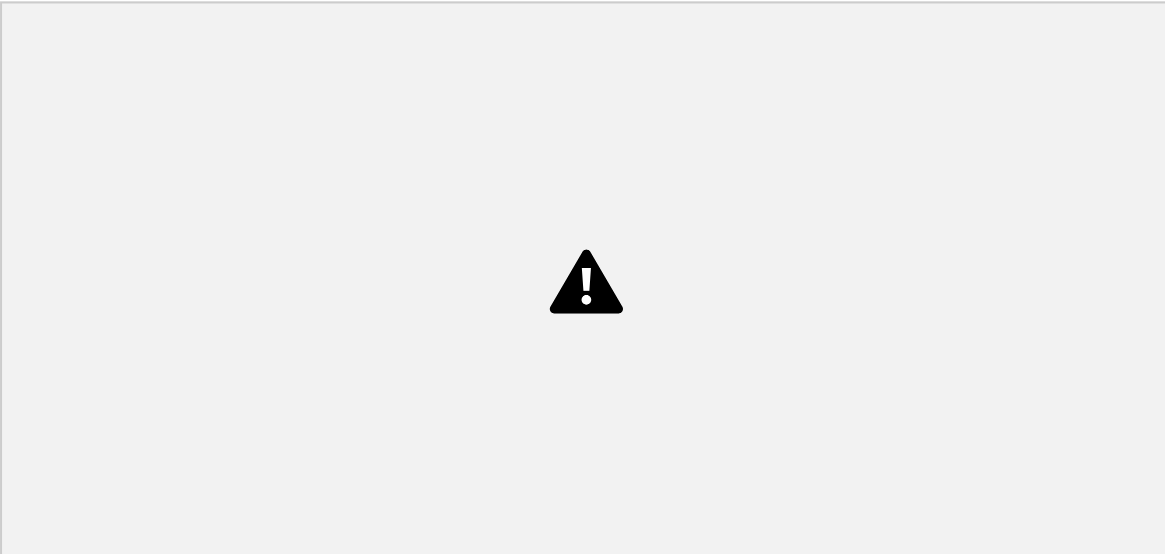


Concept of microwave heating effect on food quality

Microwaves are electromagnetic waves of radiant energy having frequency ranges from 300 MHz. to 300 GHz. corresponding to wavelength in the range of 0.001-1 m. Light is also a kind of electromagnetic wave. The electromagnetic waves that are less than 3000GHz, is classified as radio wave. Radio wave that has frequency of 300MHz to 300GHz (wave length of 1m to 1mm) is known as microwave and is positioned somewhat close to FM radio and television broadcasting brands. A microwave oven heats food by passing microwave radiation through it. Microwaves are a form of ionizing electromagnetic with a frequency higher than ordinary radio waves but lower than infrared light.

In the case of microwave ovens, the commonly used radio wave frequency is roughly 2,500 megahertz (2.5 gigahertz). They are absorbed by water, fats and sugars. When they are absorbed, they are converted directly into atomic motion and motion is converted into heat. Microwave ovens cook food "From the inside out." In microwave cooking, the radio waves penetrate the food and excite water and fat molecules pretty much evenly throughout the food. There is no "heat having to migrate toward the interior by conduction". There is heat everywhere all at once because the molecules are all excited together.

Electromagnetic wave is a wave that has two elements, such as wavelength and frequency. Wave length is about the length of top to top of the wave, frequency is number of waves that appear in a second.



Microwaves, like light, travel in straight lines. They are reflected by metals, pass through air and many, but not all types of glass, paper and plastic materials, and are absorbed by several food constituents including water. Microwave ovens are used in many other industrial fields, e.g. pasteurization of vegetables, Drying of paper or textiles, thermal treatment of pharmaceutical products and vulcanization of rubber.

Principle: - When microwaves pass into foods, water molecules and other polar molecules tend to align themselves with the electric field. But the electric field reverses 915 or 2450 million times per second (MHz.).

The molecules attempting to oscillate at such frequencies generate intermolecular friction which quickly causes the food to heat.

The major food components - water, carbohydrates, lipids, proteins and salts (minerals) - interact differently with MW. Because the primary mechanisms of MW heating are dipole rotation and ion acceleration, MW interactions with foods depend heavily on salt and moisture content

For example, Water consists of two hydrogen atoms and one oxygen atom. It doesn't have electric charge as a whole; an oxygen atom is bounding with two hydrogen atoms at an angle of 104.5°. Those atoms take a little charge of each minus (-) and plus (+) to form a dipole.

In microwave, heat is generated quickly and quite uniformly throughout the mass. Foods do not heat from the outside to the inside as with conventional heating since microwave penetration can generate heat throughout the food mass simultaneously. The microwaves can result in very rapid heating but requires special equipment, packaging materials, since microwaves will not pass through metal cans or metal foils. Microwave heating produce major differences in food appearance and other properties compared to conventional heating and reduces process time by 90%.

ADVANTAGES	DISADVANTAGES
- Cooking time is short - Destruction of nutrients is less - No physical change of foods - Melting process is easy - Sterilization effect exists - There is no flame, then treatment is easy	- Constraint with metal container - Heat force control is difficult - Water evaporation - Closed container is dangerous because it could be burst - Surface toasting is impossible

.

ATTENTIONS IN USING MICROWAVE OVEN

1. If the container is metal spark is generated and no foods heat up.
2. If food is different in ingredients heating velocity could be different. For instance the food contained more fat will be heat up fastly.
6. Bad influence to human body of microwave in microwave oven is nearly only the thermal effect. And safe level of microwave is $10mW/cm^2$. Leakage of microwave is mostly occurred in the gap of oven and door. Therefore it is important to pay attentions that gap length is not differed.

Effects of microwave on food and nutrients

The use of microwave heating for food processing applications such as blanching, cooking, and baking has a great effect on the preservation of nutritional quality of food. Furthermore, microwave heating could significantly require less energy consumption for dehydrating food than conventional method. Microwave heating is relatively fast compared to conventional heating since it does not depend on the slower diffusion process in the latter. If properly used, microwave cooking does not affect the nutrient content of foods to a larger extent than conventional heating. Most reports indicated that microwave cooking resulted in higher moisture losses compared with conventional methods. Overall, the nutritional effects of microwaves on protein, lipid, and minerals appear minimal. There is no report on the effects of microwaves on carbohydrate fraction in foods. A large amount of data is available on the effects of microwaves on vitamins.

Any form of cooking will destroy some nutrients in food, but the key variables are how much water is used in the cooking, how long the food is cooked, and at what temperature.

Nutrients are primarily lost by leaching into cooking water, which tends to make microwave cooking healthier, given the shorter cooking times it requires. Like other heating methods, microwaving converts vitamin B_{12} from an active to inactive form. The amount inactivated depends on the temperature reached, as well as the cooking time.

Boiled food reaches a maximum of 100 °C (212 °F) (the boiling point of water), whereas microwaved food can get locally hotter than this, leading to faster breakdown of vitamin B_{12}. The higher rate of loss is partially offset by the shorter cooking times required.

Spinach retains nearly all its foliate when cooked in a microwave; in comparison, it loses about 77% when boiled, leaching out nutrients.

Steamed vegetables tend to maintain more nutrients when microwaved than when cooked on a stovetop.

Microwave blanching is 3-4 times more effective than boiled water blanching in the retaining of the water-soluble vitamins folic acid, thiamin and riboflavin, with the exception of ascorbic acid, of which 28.8% is lost (vs. 16% with boiled water blanching).

In a conventional oven, the product is surrounded by hot air which heats the product from the outside and also dries the surface. In microwave heating, the entire product is heated at the same time but the heating may not be uniform.

In conventional ovens volatile flavour molecules can move from inside the product to the surface and evaporate. But in microwave heated products, the surface stays moist and cooler; loss of flavour compounds is less.

The surface of the product will also get to a higher temperature in a conventional oven. This enhances the rate of the browning reaction on the surface, which provides not only the desirable brown colour but also produces a large number of flavour compounds. But if a product is simply to be reheated, the microwave can be used.

The sensory properties of vacuum-microwave-dried and air-dried carrot slices, which were water blanched initially, received the higher ratings for texture, odour and overall acceptability as compared to the air-dried carrot slices.

The retention of volatile components responsible for flavour was more in hot air microwave drying compared to conventional hot air drying alone.

Due to high temperature and long drying time, volatile compounds are vaporized and are lost with water vapour, resulting in significant loss of characteristic flavour in dried products. Case-hardening is a common problem in dried fruits due to rapid drying. Compared with hot-air dried berries, MW-dried cranberries have better colour, softer texture.

Aim: - Preparation of Pickle.

Theory

Pickle is an edible product preserved in a solution of common salt and vinegar. Pickles are also prepared by fermentation, by lactic acid-forming bacteria, which are generally present in large numbers on the surface of fresh vegetables and fruits. These bacteria can grow in acid medium and in the presence of 8-10 % salt solution. Lactic acid bacteria are most active at 30°C.

Pickles can be prepared from fruits and vegetables like mango, lemon, amla, onion, cauliflower, cabbage, beans, cucumber, bitter gourd, jackfruit, turnip etc.

The commercial varieties of pickles can be divided into five classes.

1. Fermented Pickle
2. Oil Pickle
3. Acid Pickle
4. Mustard Pickle
5. Brine Pickle

Requirements

Raw materials, equipment and apparatus

Fruit/vegetable, sugar, Peeler, Filter cloth / sieve, Pans of suitable size, volumetric flask, measuring cylinder, Weighing balance, Potable water

Preservation with oil

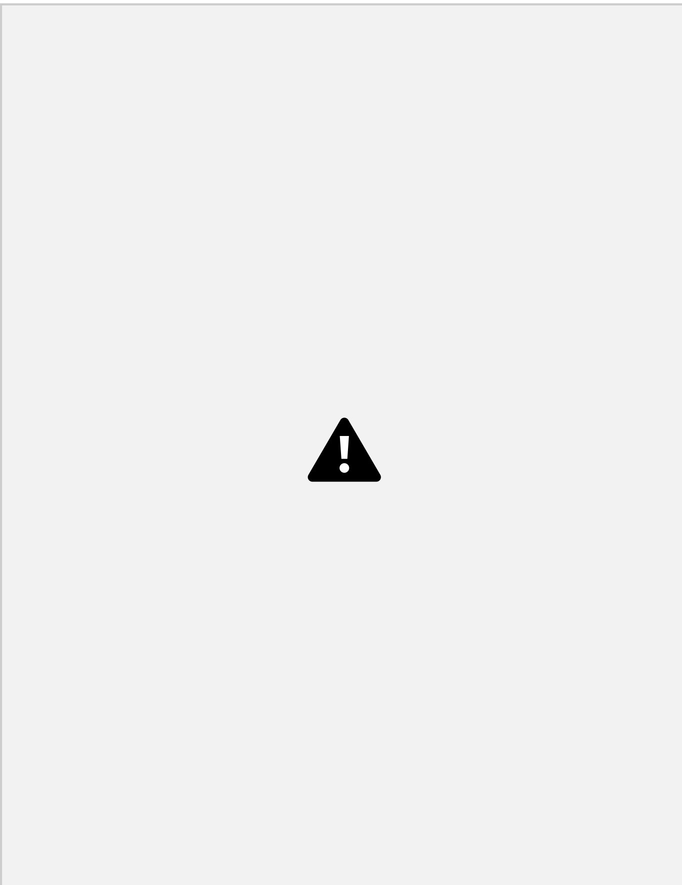
Oil pickles are highly popular in India. They are highly spiced. In India,mustard oil, rapeseed oil, sesame oil is generally used. The fruits orvegetables should be completely immersed in the edible oil. Cauliflower, lime,mango and turnip pickles are the most important oil pickles. The pickleremains in good condition for one to two years if handled properly. The fruits or vegetables should be completely immersed in the edible oil. Cauliflower, lime, mango and turnip pickles are the most important oil pickles.

Procedure

Select mature and green mangoes of fruit/vegetables
Wash mangoes properly
Preparation: - After washing the mangoes the mangoes cut into desired size and remove kernel.
After preparation dip pieces into 2% salt solution to prevent browning.
Drain extra water and dry pieces into shade for few hours.
Now heat up the mustard oil and cool. Heat of oil reduces the strong flavour of mustard oil. After cooling the spices in little quantity of oil mixed.
Now pieces of fruit mixed with oil.
After filler the pieces keep the jar for week in sun
After a week press the material to remove air and add remaining oil.
Store at ambient temp.

Precaution

Do not use metallic vessels.
The container should not impart any colour, taste, and flavour of its own to the pickle. Glass vessels, stainless steel, and aluminum containers are generally used as cooking utensils.
The spoons and measuring vessels should also be of non corrosive materials
During preparation hygienic condition should be maintained.



Mango pickle: Mango pieces 1 kg, salt 150g, fenugreek (powdered) 25g, turmeric (powdered) 15 g, nigella seeds 15g, red chilli powder 10g, clove (headless) 8 numbers, black pepper, cumin, cardamom (large), aniseed (powdered) each 15g, asafetida 2g, mustard oil 350 ml Gust sufficient to cover pieces).

Aim: - Preparation of sauerkraut

Theory:-

Sauerkraut: It is the product of characteristic flavour, obtained by lactic fermentation of cabbage in the presence of 2-3% of salt.

Sauerkraut or Sauerkohl is a German term which means *'Sour Cabbage'* Sauerkraut is extensively used in the North America (Canada and U.S.A.),Germany, Holland, France, U.K. and other European countries. Cabbage('*Brassica oleracea*) normally grown in cold climate is found to be suitable forthe fermentation purpose.

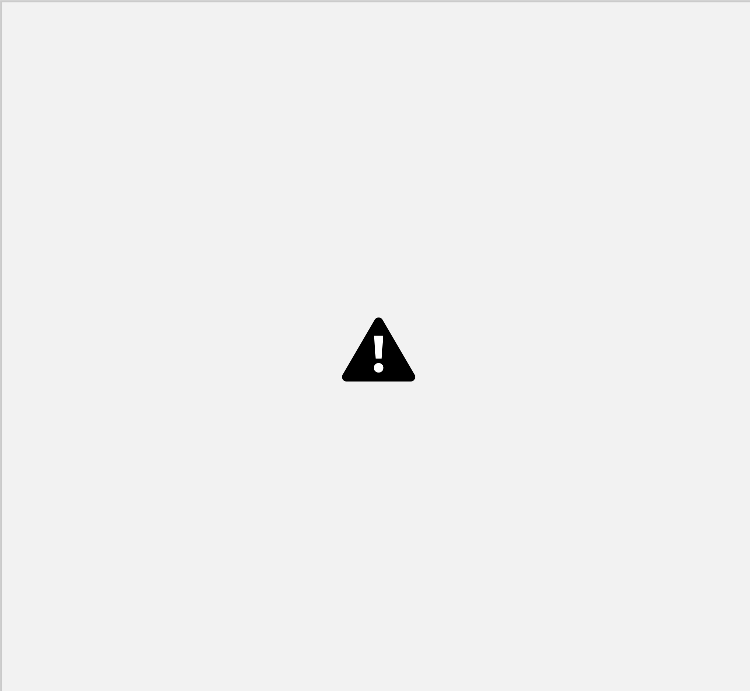
It is the clean, sound product of characteristic flavour, obtained by full fermentation, chiefly lactic of properly prepared and shredded cabbage in the presence of not less than 2% nor more than 3% of salt. It contains, upon completion of the fermentation not less than 1.5 per cent of acid expressed as lactic acid.

Requirements
Fresh cabbage, salt, plastic film, weighing balance, weight, knife, wooden vat or cement tank

Procedure
Taken fresh cabbage
Cleaned, trimmed and shredded into 2-5mm size.
Filled into wooden vats or cement tanks.
Salt is added at the rate 2.25% and mixed thoroughly.
The top portion of the vat or tank is covered with plastic
Now enough weight is applied in order to make it compact and allow anaerobic conditions prevail for fermentation. When weight is applied, the salt dissolves in the sap which is expressed by the pressure and by osmosis it comes out from the cells.
After complete fermentation which is done for about 30 days or more until 1% lactic acid is formed.
The Sauerkraut is removed from the vat and packed in cans, glass or plastic containers. In cans the fermented product is pasteurized at 74_{o}C for 3 minutes.
After that Sodium benzoate or potassium meta-bisulphite is added when product is packed unpasteurized. It is stored at + 5_{o}C.

Precaution

Sometimes fermented products are very badly spoiled by contaminating bacteria causing off flavours and colour and undesirable texture. To avoid these condition some parameters should be in control condition like:
Temperature. Lower temperature around $7\text{-}10_{o}$C favours slow growth of bacteria and thus allows good fermentation
Salt concentration
Sanitary conditions are important to control the desired fermentation. In traditional system, fermentation is allowed for 6 months.



Aim: - Preparation of brine and syrup

Material required: - stainless steel utensils, Big spoon, sugar, salt etc
Syrup

A solution of sugar in water is called syrup. The syrups are added to fruits during canning. Cans are filled with hot (79°–82°C) sugar syrup. Syrup of 10° to 55° Brix (per cent sucrose) is generally used. We can prepare sugar syrup of 20° Brix by dissolving 250 g sugar in one-liter water and of 50^0Brix by dissolving one kg of sugar in one litre water. For making syrup, cane sugar, liquid glucose or invert sugar is used but usually cane sugar is employed. Sometimes citric acid and ascorbic acid are also mixed with the syrup to improve flavour and nutritional value, respectively.

Sugar syrup is not only used for canning but also prepared for getting desired consistency of many fruit and other type of beverage products. For example squashes, carbonated beverages, etc. There are two type of sugar syrup preparation methods hot process and cold process. In cold process very low temperature is used to dissolve the sugar

Preparation of syrup

The sugar is dissolved in small quantity of water to yield heavy syrup ($60\text{-}65_0$Brix).
The cane sugar and water are heated together until a clear syrup is obtained. Heat treatment is provided through steam. Tanks with steam heated coils or steam jacketed kettle is used for the preparation of the syrup.
Sugar syrup is clarified by passing through cloth.
Then it is diluted to the desired degree Brix.

Brine

Brine is a solution of common salt in water. Brine is used in canning of vegetables. A brine of 1 to 3% salt is used at 79°-82°C. Dilute brines of 1 to 2 percent common salt are used during canning of vegetables. Salt used for canning should be at least 99 % sodium chloride (NaCl) and lower purity less than 98 % should not be used.

Preparation of brine

The salt is dissolved in small quantity of water.
The slat and water are heated together.
Brine is clarified by passing through cloth.

The purpose of adding Syruping/brining to fruits is
(1) to improve taste,
(2) to fill up the interspaces in can,
(3) aid in the transfer of heat during the processing.

Aim: Preparation of Fruit Jam

Raw materials, equipment and apparatus
1. Fruit/vegetable, sugar
2. Peeler
3. Pulper
4. Filter cloth / sieve
5. Pans of suitable size
6. Heaters
7. Volumetric flask
8. Weighing balance

Chemicals and reagents
Citric acid / ascorbic acid
Potassium metabisulphite (KMS)
Sodium benzoate

Theory:
Jam: Jam is prepared by boiling whole fruit pulp with cane sugar (sucrose) to a moderately thick consistency with out retaining the shape of the fruit.
Or

Jam is a product with reasonably thick consistency, firm enough to hold the fruit tissues in position, and is made by boiling fruit pulp with sufficient sugar.

Jams may be made from all varieties of fruits. Good, fully matured fruits are selected, washed, peeled. Thin skinned fruits do not require peeling such as Apricots, plums etc but stone can be removed by machine. Fruits should be boiled in a small quantity of water and steamed and passed through pulper and finisher to get the desired texture pulp.Most jam should be concentrated to boiling temperature of 103 to 105_0C. The end points of jams boiling vary with fruit varieties, amount of sugar and some other factors. As per FPO specification 45 parts of fruit to each 55 parts of sugar and contain 0.5-0.6% acid and invert sugar should not be more than 40%. is used for preparation of jam.

Preparation of jam

Selection of fruit: - This is the first step in the preparation of jam. In this step ripe and deep color fruits are chosen from a lot by shorting and grading

Washing: - After selection of fruits the fruits are washed with clean or plane running water.

Peeled: - After washing the fruit is peeled by using hot water and mechanical pilling.

Pulping: - After pilling the pulping of fruit is done with the help of pulpier in which the seeds and core are removed.

Addition of Sugar: - 0.80 kg of sugar is added in 1kg of pulp. 150 of water may be added if necessary.

Boiling: - Pulp and sugar concentrate is boiled with continues stirring.

Addition of citric acid: - 2.5 gm of citric acid in 1kg of pulp.

Judging of end point: - By further cooking up to 105 C or 68-70% T.S.S.

Filling: - Jam is filled into sterilized bottle.

Cooling: - After filling then cooling is done 1 to 5 Degree C.

Sealing: - After waxing the bottle are sealed with the help of sealing machine.

Storage: - After sealing the last step is storing. The jam is stored at ambient temperature 25 to 30 degree C

Observations

Determine TSS, acidity, pectin

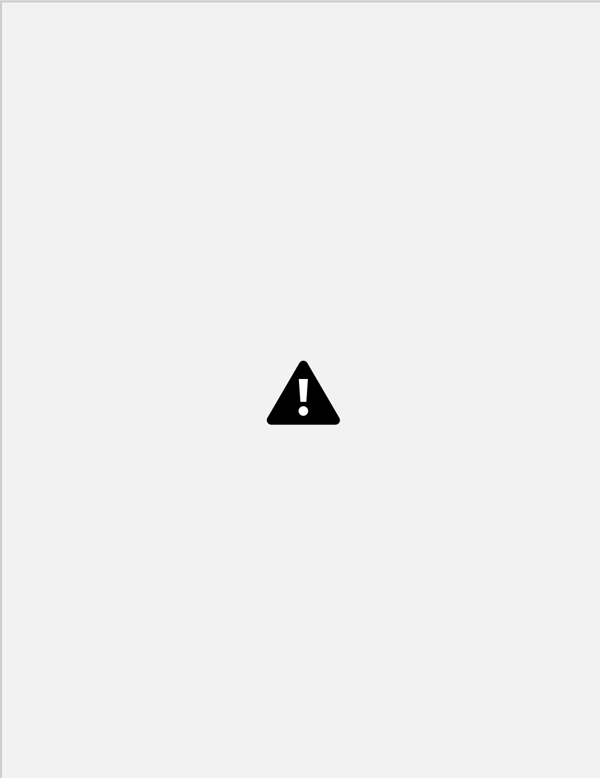
Result

Acidity of the given jam, jelly, preserve = % (w/v)

TSS of the given jam, jelly, preserve = %

PRECAUTIONS

- All equipment used in the preparation of fruit juices and squashes should be rust and acid proof.
- Copper and iron vessels should be strictly avoided as these metals react with fruit acids, and cause blackening of the product.



Aim: - Preparation of brine and syrup